STRATEGIC AIRLIFT EN ROUTE ANALYSIS AND CONSIDERATIONS TO SUPPORT THE GLOBAL WAR ON TERRORISM

THESIS

Michael C. Sere, Captain, USAF

AFIT/GOR/ENS/05-17

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT/GOR/ENS/05-17

STRATEGIC AIRLIFT EN ROUTE ANALYSIS AND CONSIDERATIONS TO SUPPORT THE GLOBAL WAR ON TERRORISM

THESIS

Presented to the Faculty

Department of Operational Sciences

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Operations Research

Michael C. Sere, BS

Captain, USAF

March 2005

AFIT/GOR/ENS/05-17

STRATEGIC AIRLIFT EN ROUTE ANALYSIS AND CONSIDERATIONS TO SUPPORT THE GLOBAL WAR ON TERRORISM

Michael C. Sere, BS
Captain, USAF

Approved:

//SIGNED//	14 March 2005
Robert T. Brigantic, Lt Col, USAF (Chairman)	date
//SIGNED//	14 March 2005
Alan W. Johnson (Member)	date

AFIT/GOR/ENS/05-17

Abstract

The Global War on Terrorism has mandated the need for additional global en route airfields. En route airfields consist of bases that are strategically located at intermediate locations between the Continental United States and the intended theater of operations. These airfields serve as refueling, crew staging, or maintenance stops for strategic airlift aircraft flying transoceanic routes. The focus of this study is to examine concepts to meet this need and to address important aspects that should be considered in devising new en route strategies. Based on various important factors associated with potential en route airfields, a goal programming based scoring methodology was used to develop an Excel based tool to aid the decision process for selecting the best future en route airfields. The factors included in this tool consist of 1)the distance from various origins to the en route of interest and the distance from the en route to various destinations, 2) the amount of parking capacity available at potential en route airfields, 3) the fuel capability present at these airfields to support strategic aircraft flow, 4) diplomatic relations with the en route host countries, 5) airfield distance from coastal seaports, and 6) the number of strategic aircraft capable airfields within a predetermined range of the potential en route. Using the developed scoring tool, 25 potential en route airfields used to transit to eight global destinations from ten different origins were studied. With the above factors assessed and examined, conclusions relating to which potential en route airfields would be the most beneficial in fighting the Global War on Terrorism are delineated.

.

Acknowledgments

I would like to express sincere thanks to my faculty advisor, Lt Col Robert Brigantic, for his consistent support of this thesis effort. With his vast background and knowledge of air mobility, he was able to help me understand all of the intricacies involved with it. In addition to my advisor, Maj. Kenneth Greenstreet a C-17 pilot, was able to help me understand everything involved with airlift as a whole. In addition to the help I received from these individuals at AFIT, the USTRANSCOM J5 personnel and the people I met at the EERISC meetings were able to provide me with the data I needed to complete my research.

Aside from the faculty, and subject matter experts I received help from, my fellow students in the GOR program at AFIT were all very helpful. Without people like them around to study with, my time at AFIT would have been much more difficult.

Finally, and most importantly, I want to express my sincere thanks to my beautiful wife. Without her continued love and support I would have never been able to complete all of my research at AFIT. This work is dedicated to her and the little one that she has in her belly right now.

Michael C. Sere

Table of Contents

List of Figures

List of Tables

Table Page

STRATEGIC AIRLIFT EN ROUTE ANALYSIS AND CONSIDERATIONS TO SUPPORT THE GLOBAL WAR ON TERRORISM

I. Introduction

Background

During the past several years, the United States Transportation Command (USTRANSCOM) has made great strides in teaming with the United States European Command (USEUCOM), the United States Central Command (USCENTCOM), and the United States Pacific Command (USPACOM) to modernize the strategic airlift en route system in Europe and the Pacific. This en route system consists of airfields that are strategically located at intermediate locations between the Continental United States (CONUS) and the intended theater of operations. These airfields serve as refueling, crew staging, or maintenance stops for strategic airlift aircraft flying transoceanic routes. The past focus on airfields in Europe and the Pacific was to satisfy the need for deploying U.S. forces to Southwest Asia (SWA) and Northeast Asia (NEA) respectively.

In 1998, USTRANSCOM, USEUCOM, and USCENTCOM formed the European En Route Infrastructure Steering Committee (EERISC) to examine requirements and shortfalls in the European en route infrastructure system. Over the next several years, the EERISC identified, validated, and collaboratively championed the need for over $700 million in fuel system hydrant, ramp and runway projects throughout the European theater to support the requirements of the National Military Strategy and, in particular, the requirements mandated by the Mobility Requirements Study 2005 (MRS-05) (McVicker, 2002). Implementing a "six-lose-one" basing strategy, the programmed 2006 European en route system consists of Moron Air Base (AB) and

Naval Air Station (NAS) Rota, Spain; Ramstein AB and Spangdahlem AB, Germany; and Royal Air Force (RAF) Mildenhall and RAF Fairford, United Kingdom (McVicker, 2002). Under the six-lose-one strategy, required airlift throughput levels to SWA can still be satisfied with the loss of use of one en route airfield due to political uncertainties, competition with other transiting aircraft, maintenance activities, adverse weather, or other causes.

Likewise, in 1999 USTRANCOM and USPACOM formed the Pacific En Route Infrastructure Steering Committee (PERISC) to examine en route requirements and shortfalls in the Pacific. Like the EERISC, the PERISC identified, validated, and collaboratively championed the need for over $500 million in fuel system hydrant, ramp and fuel storage projects throughout the Pacific theater (McVicker, 2002). Implementing a "two-lose-one" routing strategy, the programmed 2006 Pacific en route system consists of Hickam Air Force Base (AFB), Hawaii; Elmendorf AFB, Alaska; Andersen AFB, Guam; Misawa AB, Yokota AB, Kadena AB, and Iwakuni Marine Corps Air Station (MCAS), Japan (McVicker, 2002). The two-lose-one strategy is comprised of a North Pacific route (via en route airfield stops in Alaska) and a Mid Pacific route (via en route airfield stops in Hawaii and then Guam). This strategy is based on the concept that the U.S. must maintain adequate infrastructure to support 100 percent of the warfighter's throughput requirements to NEA using either route. The current European and Pacific en route systems are presented in Figure 1.

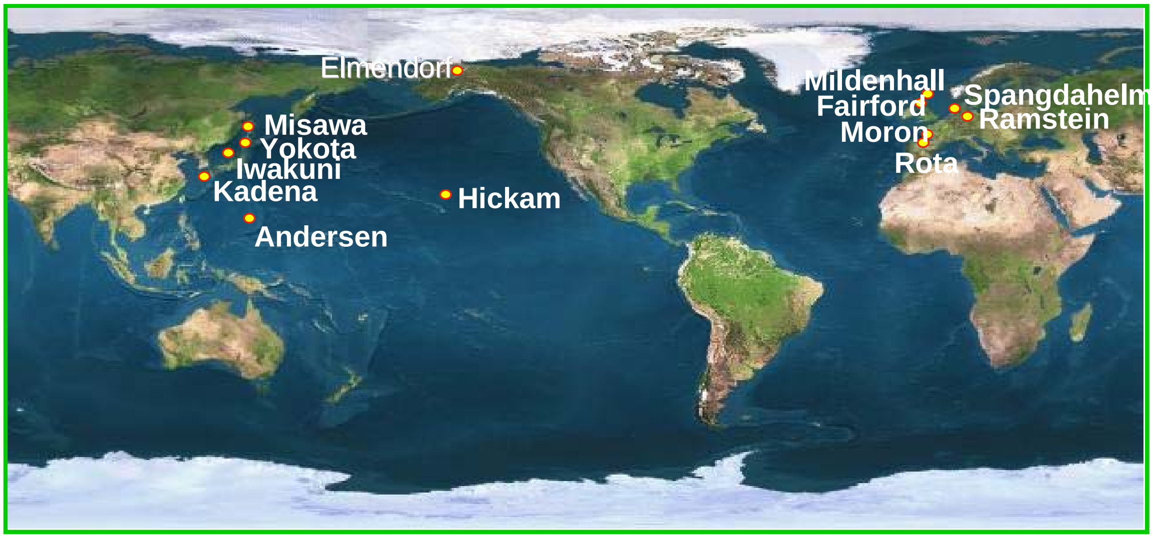


Figure 1. Current En Route Locations

Problem Statement

Despite the great successes of the EERISC and PERISC, Operation Enduring Freedom, Operation Iraqi Freedom, and other post September 11th, 2001 mobility deployment requirements have clearly demonstrated the need to adopt a more global en route capability to support the on-going Global War on Terrorism (GWOT). Consequently, the EERISC and the PERISC have been trying to assess the need for additional en route infrastructure to provide a truly global reach capability for strategic airlift. The focus of this research is to examine concepts to meet this need and to address important aspects that should be considered in devising new en route strategies and establishing new en route airfields. For the purpose of this study strategic airlift aircraft are considered to be the C-5 Galaxy and the C-17 Globemaster III.

Research Questions

In order to thoroughly analyze the possible en route airfields for the United States Air Force inventory, several questions must be examined. In order to build an effective model and answer the overarching research objective, the following questions will be explored:

- How does the distance to the en route airfield effect aircraft and total fleet throughput?
- How do airfield parking capabilities, characterized by maximum on ground (MOG) values interact with given aircraft fleet mixtures and payloads?
- What airfields can provide the most benefit to support the Global War on Terrorism (GWOT) as en route airfields?

The rest of this document is organized as follows. Chapter II presents the literature that was reviewed pertaining to the en route system. Chapter III reviews the methodology used to approach this problem. Chapter IV presents the results and analysis obtained by using this methodology. Finally chapter V presents the conclusions and recommendations of the study as a whole.

II. Literature Review

Introduction

This chapter reviews recent pertinent studies and analyses related to the en route strategy subject. Although articles and analyses relating to the en route system are somewhat scarce, the studies that were obtained were examined and are presented here.

En Route Strategic Plan

The European and Pacific areas of responsibility (AORs) have both been looked at extensively by their respective infrastructure committees. While this separation is necessary due to their different focus and geographic regions, a joint compilation of both EERISC and PERISC studies is important. Today's vision of a global en route infrastructure necessitates the compilation of all AOR studies into a single analysis. One attempt to bring these two AORs together into a single study was done by the En Route Strategic Plan. This plan is formed to "provide a review of the ERS since Desert Storm, document the current ERS strategy, review the ERS studies applied against the strategy which identified ERS deficiencies, and document the programmatic actions the Mobility Air Forces have taken to ensure the ERS will be able to meet the warfighters requirements in the first quarter of the new millennium" (McVicker, 2002).

In the 2002 version of the En Route Strategic Plan, a summary of recommendations for improvements and modernization efforts is provided for both the European and Pacific en route systems. McVicker cites that the pacific en routes have been left to decay somewhat since their last major activities in the WW II and Vietnam era. The bases in this AOR were built up with large ramp space to support mobility operations, but the pipeline capabilities and hydrant availability prove to hinder the throughput possibility at these bases without the addition of further infrastructure modifications. The European en route system, on the other hand, has seen more recent activity. However, while the increased usage of this en route system has provided it with more visibility, there were still shortfalls. The European en route system has a good deal of infrastructure modifications planned but are still far from complete. Many of these improvements have been planned for the Pacific en route airfields as well and will hopefully be complete in the coming years (McVicker, 2002).

European Area of Responsibility (AOR) Studies

Due to the increased presence and threat of terrorism throughout the world, the capabilities of the military en route system have undertaken a good deal of scrutiny. With current terrorism threats being most prevalent in Southwest Asia, the European AOR has received attention. The ability of this AOR to fully support large scale military operations through this area has been studied thoroughly by the EERISC. In one particular study, USTRANSCOM looked at six particular airfields to gain a thorough understanding of the capabilities present in the European en route system. The six specific bases analyzed in this study were Ramstein AB, NAS Sigonella, Incirlik AB, Moron AB, NAS Rota, and RAF Fairford. These airfields were deemed important to study. In this research effort, the United States Transportation Command (USTRANSCOM) Aerial Port of Debarkation (APOD) model and its component Aerial Throughput Tool (ATT) were used for a 'quick-look' assessment. The APOD model's airfield simulation tool (AST) was also used to get a detailed throughput analysis of each airfield. Additionally, three mixes of C-5 and C-17 aircraft were used in the analysis. One fleet was made up of all C-5 aircraft, another was made up of all C-17 aircraft, and the third fleet contained a 50/50 mix of C-5 and C-17 aircraft. Using the given analysis tools, certain Limiting Factors (LIMFACs) were obtained for the bases analyzed. In the analysis comprised of all C-5 aircraft, the LIMFAC was consistently parking availability. For the scenario containing all C-17 aircraft, maximum sustained fuel receipt was the LIMFAC. The amount of throughput, measured as departures per day, achieved at each of the airfields are presented in Table 1 as obtained from the ATT model.

Table 1. FY 05 En Route Throughput Capacity (departures/day)

En Route Airfields	C-17 Fleet	C-17/C-5 Fleet Mix	C-5 Fleet
Ramstein AB	73	65	53
NAS Sigonella	33	29	16
Incirlik AB	39	30	19
Moron AB	52	45	38
NAS Rota	68	55	44
RAF Fairford	50	45	39

As can be seen in Table 1, the LIMFAC associated with parking availability for the C-5 fleet has a greater impact than the LIMFAC of sustained fuel receipt for the C-17 fleet. It is also evident that the smaller C-17 is able to provide a greater throughput than that of the larger C-5 aircraft when Maximum on Ground (MOG) is a constraint. This greater throughput for the C-17 relates to lesser MOG, fuel requirements, and shorter ground times (Mahan et al, 2002).

Interim Brigade Combat Team Study

The Interim Brigade Combat Team (IBCT) Air Mobility Deployment Analysis was completed by USTRANSCOM, Air Mobility Command (AMC), and the Military Traffic Management Command Transportation Engineering Agency (MTMCTEA) in 2002. This study was conducted in order to present the deployment capabilities of the IBCT.

The Army IBCT Organizational and Operational Concept calls for "the entire IBCT to deploy within 96 hours of first aircraft wheels up and begin operations immediately upon arrival at the Aerial Port of Debarkation (APOD)" (IBCT, 2002:1). In this study several assumptions were made and limiting factors were incrementally relaxed in order to improve closure times. A MOG value of 7 at the destinations was used and baseline values of 48 C-5 and 42 C-17 aircraft were utilized. As a result of the study findings, several recommendations were developed. The most important finding of the study impacting the closure of the IBCT was that the hot cargo requirements significantly impact the closure time of any fleet studied. The literature states that "reducing to 25% hot cargo improves average closure by 36%" while "increasing the hot cargo requirement to 75% lengthens average closure by 43% with every scenario becoming infrastructure constrained" (IBCT, 2002:3). These facts provide proof that hot cargo has a significant impact on the closure time of any fleet of aircraft. An additional finding of the IBCT analysis was that simulation runs with an enhanced fleet of 84 C-17 and 60 C-5 aircraft added 1,400 miles of global reach, at the same closure rate, to destinations. The comparison is made against the baseline fleet of 42 C-17 and 48 C-5 aircraft. This finding points out that continued requirements for the C-5 and additional C-17 aircraft procurement are essential in order to meet the needs of the IBCT fleet.

Planning Factor Graduate Research Paper (GRP)

Airlift analysis is often examined by using the planning factors presented in Air Force Pamphlet 10-1403 Air Mobility Planning Factors (AFPAM 10-1403). While these planning factors are essential in producing analytical work, the factors contained in AFPAM 10-1403 are dated. The factors contained in this document are based on the historical averages from Operations Desert Shield and Desert Storm. Although newer versions of AFPAM 10-1403 (including the current version from December 2003) have been published, the planning factors have not been updated. They are also “simple mean values which help planners make gross estimates about military requirements” (Pelletier, 2004:15). C-5 and C-17 aircraft ground times and payloads were analyzed by Pelletier based on more recent data from Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF). Pelletier found that actual aircraft payloads were much less than the planning factor values and operational ground times were longer. The combined effects of these findings can have significant impact on future airlift analysis and war plans.

Strategic Airlift Analysis Tools and Techniques

The primary starting point to study the airlift capability of the United States Air Force is simple algebraic equations. Some equations relate to how many missions need to be flown in order to meet a movement goal. Others relate more to the capabilities present and available to support these missions. Brigantic and Merrill lay out many important algebraic relationships that help to define airlift capabilities (Brigantic and Merrill, 2004).

One of the formulas is the definition of MOG. Some studies refer to working MOG, which is the number of aircraft of a given type that can be worked on (serviced or unloaded) at the same time. Other studies simply refer to parking MOG, which is the number of aircraft of a given type that can be parked concurrently at an airfield. Brigantic and Merrill demonstrate the computation of working MOG which is calculated through several important equations. As an example, the parking MOG values at the en route airfields of Ramstein AB and RAF Fairford is 19 and 8 respectively. The MOG value of 19 at Ramstein is one of the highest values at any of the current en route airfields. The 8 value at RAF Fairford, however, is more of a typical value for current en route airfields. The general equation for calculating MOG is:

$$Maximum\ on\ the\ Ground, MOG = \frac{Limiting\ Ground\ Time}{Flow\ Interval} \tag{1}$$

In the above equation the limiting ground time is described as the longest planned stop in the cycle. The cycle can be defined as the full round trip from debarkation to destination and back. The limiting ground time is generally dependent upon "ground events required at the on-load location" (Brigantic and Merrill, 2004:5). Additionally, limiting ground time "presumes a continuous flow of aircraft without pronounced delays for aircraft breaks, non-scheduled maintenance, or ground delays due to other factors (crews, air traffic, weather, etc.)" (Brigantic and Merrill, 2004:5). The flow interval, on the other hand is a more complex formula that takes into account the different amount of time between actions such as aircraft service, aircraft cycles, and stage crew availability. The flow interval can be calculated by simply taking the maximum of stage crew interval, flying hour capability interval, aircraft allocation interval, and station interval. The longest one of these is considered the LIMFAC for flow interval. This flow interval is important to MOG calculations because it represents how often the start of a new strategic airlift cycle can be expected. If the flow interval and the aircraft allocation interval are the same then the number of aircraft available is the only constraining factor.

General Accounting Office En Route Report

The United States General Accounting Office (GAO) often produces reports for different House of Representative and Congressional committees and subcommittees. These reports are produced to help with the general oversight that these congressional committees provide. The "Management Focus Needs on Airfields for Overseas Deployment" paper produced by the GAO points out several limitations present in the ERS as well as recommendations to overcome these shortfalls (GAO-01-566, 2001). This particular report addressed three general areas. These areas included "1) whether en-route airfields have the capacity to meet the requirements of the national Military Strategy, 2) what are the causes of any shortfalls and DOD's plans to correct them, and 3) whether DOD has the information and management structure needed to ensure that the operations of the ERS can be carried out efficiently and effectively" (GAO-01-566, 2001:1). Of all the shortfalls that this paper gathered, the most important one related to the "predicted lack of capacity of the ERS airfields to meet delivery schedules required by the National Military Strategy" (GAO-01-566, 2001:2). With respect to this particular shortfall, the GAO report explains that "the DOD believes that projected improvements to the ERS will largely eliminate the shortfall by 2005" (GAO-01-566, 2001:2). If this particular shortfall is overcome in the next few years, the ERS will be in a positive position to support global mobility.

Summary

Several articles and papers relating to the en route system have been completed by USTRANSCOM and AMC. A limited number of these research efforts were presented here, however, due to the overall classification of or the inability to retrieve them. If some of the work done by USTRANSCOM or AMC was not classified, many times it only exists as a briefing or an internal memo. Since most of the work relating to the en route system is so hard to come across, analysis of this infrastructure is difficult to complete. In addition, much of the research that has been completed regarding the en route systems relates to current world events that does not support the en routes future missions to support the GWOT. The analysis and considerations presented in this paper will therefore be more valuable to those who wish to thoroughly understand and study this system as it relates to current world events.

III. Methodology

Introduction

This chapter lays out and describes the procedures incorporated used to complete this study. An initial attempt to study this problem via a simulation approach failed to produce meaningful results, but the methodology is briefly reviewed in this section. After a good deal of research into the intricacies involved with the European and Pacific En Route Systems, a more useful approach to study the global en route issue was devised. This approach will be discussed in this section as well. Finally, to conclude this chapter of research, the approach assumptions and application will be reviewed.

Initial Approach

The Air Mobility Operations Simulation (AMOS) is a modeling tool used by AMC to study the many aspects of strategic airlift. This AMOS simulation requires inputs relating to several facets of the air mobility system. In order to make a run of any particular scenario, the resources available, the requirements for delivery (e.g., short tons requested), and the aircraft routes must all be input into the simulation. The resources refer to the number and type of aircraft available for transportation, the amount of cargo that each aircraft can or will carry based on aircraft size definitions, and available times for the aircraft to take off or land in the simulation. Once all of the necessary data is input into the model and the model is executed, the outputs include many reports that define results of the simulation, the statistics of the aircraft involved, and the overall summary of the missions included in the model, to name only a few. The multitude of outputs associated with an AMOS model run provides good insight into the detailed workings of any mobility operation.

An initial plan to study en route considerations was to analyze the "optimality" of the 3,500 nm planning factor as an optimal en route distance for global airlift. This distance was defined as planning factor for mobility transportation based upon the lens concept. The lens concept is based on the distance that the aircraft can travel efficiently from both the origin and the destination. Where these distance or arcs overlap defines the lens. The idea then is to locate en routes inside this lens for efficient strategic airlift throughput

By specifically analyzing the throughput capabilities given different en route distances from a specified origin and destination, the true optimal en route length would be more narrowly defined. The extensive information that can be obtained from the AMOS model is very helpful in any airlift analysis. In an attempt to look into the considerations for global airlift, a factorial experiment was planned. This experiment would use statistics such as short tons per day (Stons/Day) as the response variable, based on low and high levels of MOG, three levels of fleet mixture, and 7 levels of distance to en route airfields. With all of these variables defined and after running a factorial experiment (Appendix A), a response surface could be produced to determine throughput as a function of en route distance for each level of MOG and fleet mixture.

This factorial experiment appears to be a good analysis tool for airlift operations if the response values are easily retrieved. The difficulty of operating the AMOS simulation, however, made it difficult to comprehend output metrics. Even with help from the Air Force office in charge of the model, consistent results could not be achieved.

Ultimately, since the simulation provided a good look into the distance traveled by each aircraft studied, the AMOS model helped with the realization that the optimal point to locate an en route between any origin and destination pair is simply the midpoint between that pair. With this realization, it was decided that a goal programming based approach would be a better methodology for assessing en route potential. This methodology will be discussed next.

Goal Programming Methodology

After the AMOS simulation approach was abandoned, different methods were studied in order to obtain a useful analysis tool. Based on various important factors associated with potential en route airfields, a goal programming methodology was used to develop an Excel based tool to aid the decision process for selecting the best future en route airfields and potential infrastructure improvements at those airfields. The factors included in this tool consist of 1) the distance from various origins to the en route of interest and the distance from the en route to various destinations, 2) the amount of parking capacity available at potential en route airfields, 3) the fuel capability present at these airfields to support strategic aircraft flow, 4) diplomatic relations with the en route host countries, 5) airfield distance from coastal seaports, and 6) the number of strategic aircraft capable airfields within a predetermined range of the potential en route. These factors will be described further in the next section.

Goal Program Setup

In order to determine optimal en route airfields for supporting the GWOT, every feasible origin, destination, and en route airfield could be enumerated and analyzed individually. This approach, however, would take a good deal of time and effort to complete. A goal program based methodology can be setup to solve this problem more quickly and easily. The purpose of the goal program presented here is to minimize the deviations from a set of goals defined for potential en route airfields. As an introduction to the goal program based methodology a general goal program setup is provided next.

The general goal program formulation is (Goichechea, 1982:101):

$$\text{Min } Q = \sum_{i=1}^{p} (w_i^+ d_i^+ + w_i^- d_i^-)$$

$$x \in X$$

$$F_i(x) - d_i^+ + d_i^- = T_i \tag{2}$$

$$d_i^+, d_i^- \geq 0, \; i = 1, 2, \ldots, p$$

Q = Objective function value

w_i^+ = weight associated with a positive deviation

w_i^- = weight associated with a negative deviation

d_i^+ = positive deviation from goal

d_i^- = negative deviation from goal

T_i = target for goal i

$F_i(x)$ = Function value associated with a vector of decision variables x

Goal Program Definitions

Using the basic goal programming methodology, a goal programming based scoring technique was devised for this study. The goals and their target for this model are as follows (each of these are discussed in more detail below):

1) Distance goal, representing the longer of its two legs, or simply one half of the distance from origin to destination
2) En route MOG goal equal to or greater than 6
3) The en route fuel availability should be rated at least two on a scale of one to three
4) En route airfield has at least 500 airfields located within 1,750 nm of it,
5) En route airfield has diplomatic relations with the en route host country score of at least three on a scale of one to three

6) En route airfields should have a proximity to seaport value of at least two on a scale of one to three.

The purpose of the goal program based methodology is to find the potential en route airfields which minimize the sum of the weighted percent deviations based on each goal and its associated weight. The value that is used to ascertain the sum of weighted percent deviations is given by Q. A summary of the goal program setup is provided in Table 2.

Table 2. Goal Program Setup

Goal #	Goal	Symbol	Range	Target	Negative Deviation	Positive Deviation	Negative Weight	Positive Weight
1	Critical leg, $\max(l_1, l_2)$	L	$D/2 \leq L \leq D$	$D/2$	d_1^-	d_1^+	0	w_1^+
2	En route wide-body aircraft parking MOG	m	$0 \leq m \leq 20$	6	d_2^-	d_2^+	w_2^-	0
3	En route fuel capability	f	$1 \leq f \leq 3$	2	d_3^-	d_3^+	w_3^-	0
4	En route country diplomatic relations	r	$1 \leq r \leq 3$	3	d_4^-	d_4^+	w_4^-	0
5	En route proximity to coastal seaports	c	$1 \leq c \leq 3$	2	d_5^-	d_5^+	w_5^-	0
6	Airfields within 2,250 miles of en route	a	$0 \leq a \leq 1,500$	500	d_6^-	d_6^+	w_6^-	0

The goal programming based scoring technique which minimizes the Q value is:

$$
\begin{aligned}
&\min Q \\
&\text{where} \quad Q = \begin{cases} \sum_{i=1}^{6} \dfrac{w^{-}{}_{i} d_i^{-} + w^{+}{}_{i} d_i^{+}}{t_i} & l_1 + l_2 \leq 8{,}500 \\ 1 & l_1 + l_2 > 8{,}500 \end{cases} \\
&\text{subject to} \\
&L + d_1^- - d_1^+ = T_1 \\
&m + d_2^- - d_2^+ = T_2 \\
&f + d_3^- - d_3^+ = T_3 \\
&r + d_4^- - d_4^+ = T_4 \\
&c + d_5^- - d_5^+ = T_5 \\
&a + d_6^- - d_6^+ = T_6
\end{aligned} \tag{3}
$$

D = overall en route range from origin to destination

$L = \max(l_1, l_2)$ = limiting factor leg distance or critical leg

m = en route wide-body aircraft parking MOG

f = en route fuel capability

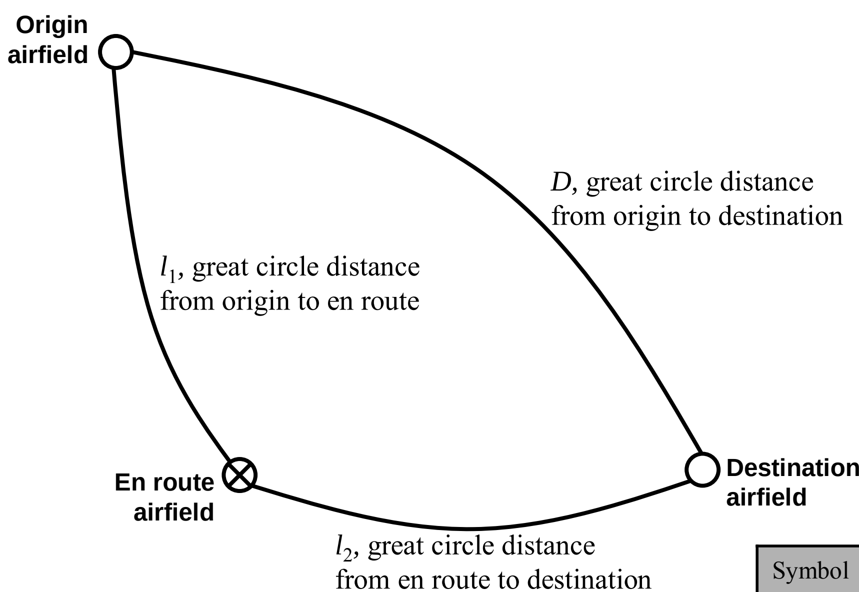
r = en route country diplomatic relations

c = en route proximity to coastal seaports

a = number of airfields within 1,750 nm of the en route

T_i = Target defined in the model for the i factor considered

The critical leg length, L, represents the longer leg distance of the origin to en route or en route to the destination. Since the amount of cargo that can be carried on an aircraft is inversely proportional to the distance traveled, the longer of the two legs flown determines the amount of cargo that can be carried on that aircraft. This is why the longer of the two legs is considered the LIMFAC, and is the only one of importance when calculating the distance goal deviation value. The critical leg concept is demonstrated in Figure 2.



Symbol	Range	Target
L	$D/2 \leq L \leq D$	$D/2$

$$\text{Critical Leg } L = \max(l_1, l_2) \rightarrow D/2 \leq L \leq D \quad (4)$$

Figure 2. Critical Leg Distance

If the overall en route range from origin to destination is less than 8,500 nm then an overall weighted percent deviation, Q, is calculated for that en route. If this value is greater than

8,500 nm, a maximum value of 1 will be assigned. This differentiation helps penalize the routes that are infeasible as they would probably never be chosen by AMC

The second factor included in the goal program analysis is the widebody parking MOG available at the potential en route airfield. The amount of parking space that can be used is an essential factor in determining the number of aircraft that can travel to and from any base. For the MOG values included in the model, widebody was used because C-5 and C-17 aircraft are the ones assumed to be landing and taking off from these airfields for the purpose of this analysis. Although C-17 aircraft are not strictly considered to be widebody aircraft, for the purpose of this study they were assumed to be widebody. The variable representing widebody MOG in this analysis is defined to be m.

The fuel capability present at an airfield is a factor that along with MOG, concurrently limits the number of aircraft that can park at a specific airfield. The number of gallons that an airfield can provide daily would be the best values to use in this analysis. Unfortunately, since the data is limited for potential new en routes, the Joint Petroleum Office (JPO) at USTRANSCOM provided estimated values for the purpose of this study. Although a precise number for the number of gallons of fuel present at each airfield could not be retrieved, an overall fuel capability value of one two or three based on the characteristics previously mentioned was provided. This value represents the overall usefulness of the airfield with respect to its fuel capability. The airfield receives a one if it is poor, two if it is average, and a three if it has a considerable fuel capability. This variable is represented as f in the model.

Diplomatic relations with any potential en route airfield's country is also essential. If a certain airfield scores well on all factors modeled, but the United States has poor diplomatic relations with the host country, a choice to include it as an en route may not be a good idea. In order to retrieve the diplomatic relations that are present between the United States and the host country, a U.S. Department of State database was consulted. Within this database a background of the particular country was provided. The background section had paragraphs that were dedicated to United States and host country relations. After assessing the state of affairs in these paragraphs, and comparing them with other countries, a value for this factor was determined. Based upon the information contained in this database, each potential en route airfield was assigned a value of one if the relations are poor, two if the relations are good, and three if they are exceptional. In our analysis, USTRANSCOM purposely chose not to include any countries deemed to have poor relations with the United States. Therefore, all potential en route airfield host countries had a diplomatic relations score of two or three.

The factor representing the potential en route's proximity to coastal seaports is modeled with the variable c. The distance to coastal seaport that was collected consisted of a straight line distance from the airfield to the nearest ocean. For the sake of simplicity, the distance to a coastal seaport was assumed to be directly to the ocean from each particular airfield. Even if a seaport does not exist at that particular location, the United States has and continues to develop the ability to load and unload its ships without a seaport.

The final factor which represented the number of C-5/C-17 capable airfields within 1,750 nm of the en route was modeled with the variable a. The distance used for this factor was chosen because this is the distance representing "the point of safe return" for a C-5 or C-17 aircraft. In order to obtain the number of airfields located within this distance of the potential en route airfield, the Lockhead-Martin developed "Airfield Reference Program" was used. Based on the average number of airfields within this range of any given region, a value obtained for this factor greater than 1,000 is considered to be fairly high while values below 200 are considered to be somewhat low. For example, the number of C-5/C-17 capable airfields within this range of Ramstein AB is 1,013, some airbases such as Augusto Severo have only 102 of these airfields within the given range. A graphical depiction of this example is provided in Appendix B.

In summary, the score for each factor contains either a raw number that the variable represents, or a number of one, two, or three. Again, values are one if the assessment is very good, two if the assessment is fair, and three if the associated assessment is poor. The factors where a raw number was included provides more fidelity than the factors made up of discrete values. This fidelity is achieved because the raw numbers provide a more exact deviation from the goal. In the factors including one of three discrete values, there are only one or two different deviations that can be achieved. For the factors containing raw number values, the deviations from the goals may consist of numerous values. Since that the factors made up of raw numbers can achieve a larger number of deviations, the fidelity associated with these factors is much higher.

Scenario Setup

In order to assess en route airfield performance and compute their Q scores, a set of specific origins, en routes, and destinations must be delineated. While most airlift missions depart from either the east coast at Dover AFB, McGuire AFB, Charleston AFB, or from the west coast at Travis AFB, McChord AFB, more origin airfields needed to be considered. This is because this analysis examined only a single en route stop in any flight. Since many potential destinations throughout the world are too far from the CONUS to be reached with only one stop, this study also used several of the existing en routes in Europe and the Pacific as origins. Specifically four en routes were considered as origins in both the European and Pacific theaters in this analysis. These airfields were, Travis AFB, Dover AFB in CONUS, NAS Rota, Lajes

AB, Ramstein AB, and Incirlik AB in the European region and Elmendorf AFB, Hickam AFB, Yakota AFB, and Anderson AFB in the Pacific region.

Next, a list of destinations was developed. Terrorism could potentially erupt in any area of the globe. With this in mind, destination airfields were selected at various and diverse locations around the world. Specifically, destinations were chosen in the following geographic regions: Central Asia, Southern Asia, Southeast Asia, Northeast Asia, Southern South America, Western Africa, Southern Africa, and Southwest Asia. The specific destination airfields used in the model for these geographic regions were as follows (It is noted that these airfields were arbitrarily chosen as points of reference):

1) Central Asia: Lahore, Pakistan
2) Southwest Asia: Baghdad International, Iraq
3) Southern Africa: Waterkloof, South Africa
4) Western Africa: Monrovia, Liberia
5) Northeastern Asia: Seoul AB, South Korea
6) Southern Asia: Gao airfield, India
7) Southeast Asia: Dili (East Timor), Indonesia
8) South America: Bahia Blanca, Argentina

Figure 3 shows the complete set of origin airfields and destination regions included in this study.

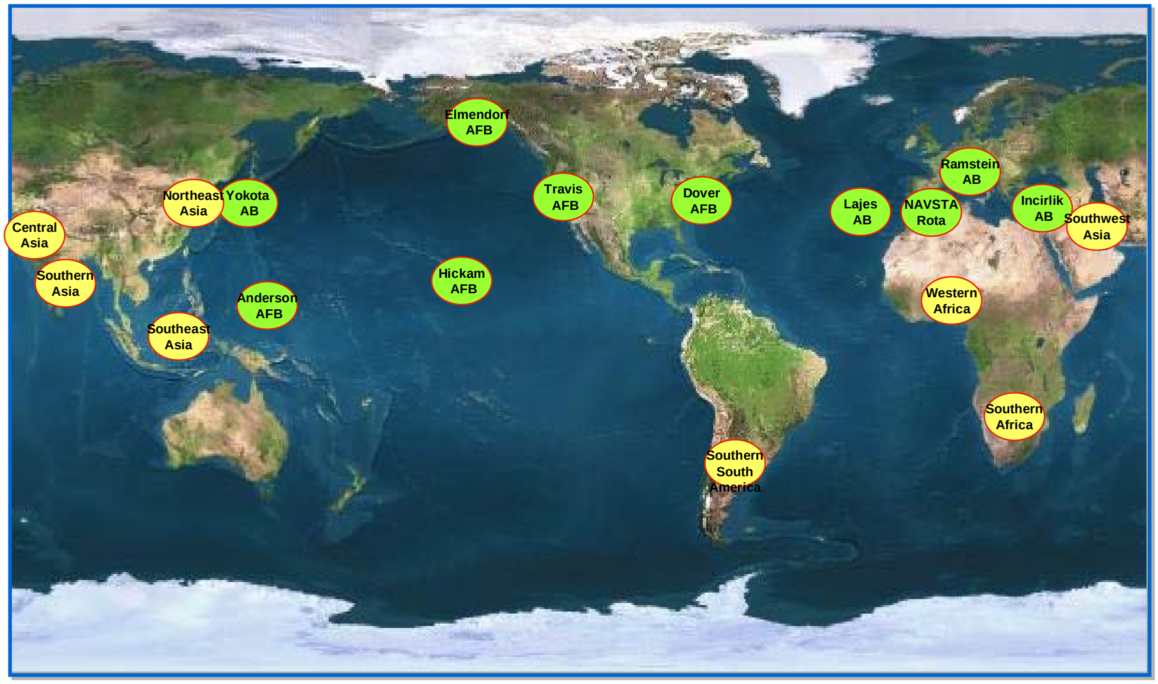


Figure 3. Origins and Destinations

The final and most important airfields that need to be considered in this study are the potential en route airfields. Working with USTRANSCOM J5 (Plans, Programs and Policy Directorate), a set of 25 potential en routes around the globe was developed for this study. These airfields are summarized in Figure 4 along with the existing European and Pacific en route airfields.

Figure 4. Existing and Potential En Route Airfields

Assignment of Weights

As mentioned earlier, in order to develop weighted percent deviations from a stated goal, weights need to be attributed to each particular deviation. The weights placed on each deviation play a large part into the *Q* value obtained. For example, if an unnecessarily high weight value was assigned to a somewhat trivial goal, this goal could almost by itself, influence which en route base performs the best. This makes the creation of the goal program weight values critical in this analysis. The flexibility of the goal program tool that was ultimately created for this study allows the user to choose the weights associated with each particular goal from a drop down menu. As will be discussed later, in addition to choosing the weights from a drop down menu, the origin and destination airfields as well as all of the assigned targets can be changed by the user. As the values are changed, a sensitivity analysis can be performed or different user preferences can be specified. The method used to determine the weights used in this study is presented next.

Value focused thinking (VFT) is an approach undertaken when several alternatives must be ranked in order to select the best one. This approach is sometimes also referred to as multi-objective value analysis. Within this analysis, a value function must be determined which combines multiple evaluation measures into a single overall measure of the value for each alternative (Kirkwood, 1997). Several intuitively reasonable combination procedures exist, but due to the problems and difficulties associated with each procedure, it is important to choose an appropriate one for each particular analysis to be done. The most basic of all procedures is the simple averaging technique. With this technique, the scores for each evaluation measure are simply averaged together. As part of the sensitivity analysis presented later in this study, the method employed before a simple average can be computed, a decision must be made as to which measure is preferred high and which is preferred low.

Another more applicable approach is to associate weights with each particular evaluation measure. Given there are six factors in this study to be combined for an overall score, the weights associated with each factor should sum to one. Simply stated, the weights should relate to the relative importance of that factor on a measurable result. The weight representing the most important factor should have a higher weight while the least important weight would have a smaller one.

Before assigning the weights, the basic attributes of the projects goals needed to be studied. To obtain these attributes, USTRANSCOM personnel were interviewed for their expertise and insights about these goals. With the given USTRANSCOM guidance, each particular goal was rank ordered based upon its relative importance. The rank ordered goals were then analyzed using a "100 Ball" weighting technique.

In the final goal program used to calculate each en route's *Q* value, the following weight values were used:

1) Distance: 0.20

2) MOG: 0.25

3) Fuel capability: 0.25

4) Diplomatic relations: 0.15

5) Seaport proximity: 0.075

6) Airfield proximity: 0.075

These weight values were calculated based upon USTRANSCOM's overall inputs combined with a "100 Ball" weighting technique. As stated above, each of these values can easily be changed by the user and recalculated based upon alternate weights for different decision makers.

Assumptions

Several important assumptions in this analysis were necessary. While these assumptions are not extraordinary, they need to be described so the results of the analysis can be thoroughly understood upon inspection or altered in the future. A summary of these assumptions are as follows

1) Only one en route stop was modeled. Routes that were greater than 8,500 nm were not considered in this research effort because they would most likely require more than one en route stop.
2) Specific aircraft capabilities and airfield personnel requirements were not included in the model for this analysis.
3) Straight line distance from a potential en route to the ocean was used to obtain the "en route distance to seaport" values.
4) Potential en route fuel capacity was retrieved from the JPO at USTRANSCOM J5 (Plans, Programs and Policy). These values would be ideally, based upon daily gallons of fuel available. However, as mentioned earlier, these data points were not available for all of the potential en route airfields. Accordingly, they were given a value based on the best assessment and expertise of the USTRANSCOM planners and JPO.
5) C-17 aircraft are modeled as widebody aircraft.

Global En Route Scoring Technique

The goal program methodology used in this study is somewhat different from the standard form that might be used. The reason for this difference relates to the solution space of the problem. Generally, numerical feasible solutions are created with the inclusion of constraints. In this case, the numerical values that can be obtained are predefined by the airfields chosen in the study. That is, it is possible to enumerate the *Q* score for each en route airfield as a function of the origin and destination pairs. As such, it was not necessary to use a mathematical programming solver routine to optimize *Q* for each scenario. Rather, the min *Q* score is simply found by examining the scores for each scenario. Thus, for each scenario an "optimal" en route is known. Figure 5 shows an example of the GERST spreadsheet tool.

Origin	Destination	MOG Goal	Fuel Goal	Diplomatic Goal	Seaport Prox Goal	Airfield Prox Goal
INCIRLIK C	LAHORE	6	2	3	2	500
Distance Weight	**MOG Weight**	**Fuel Weight**	**Diplomatic Weight**	**Seaport Prox Weight**	**Airfield Prox Weight**	**Weight Sum**
0.2	0.25	0.25	0.15	0.075	0.075	1

Origin	Destination	Distance	Lat Origin	Lon Origin	Lat Destination	Lon Destination
INCIRLIK CDI	LAHORE	1947	37.0000	-35.4167	31.5167	-74.4000
Distance Goal - D/2	**MOG Goal**	**Fuel Goal**	**Diplomatic Goal**	**Seaport Prox Goal**	**Airfield Prox Goal**	
973.62	6	2	3	2	500	
w1 +	**w2 -**	**w3 -**	**w4 -**	**w5 -**	**w6 -**	**Weight Sum**
0.20	0.25	0.25	0.15	0.075	0.075	1.00

Potential En Routes	Country	ICAO	Q	Lat En Route	Lon En Route	L1 (Leg 1)
Darwin Intl	Australia	YPDN	1.0000	-12.4088	-130.8667	6104
Bahrain Intl	Bahrain	OBBI	0.0639	26.2667	-50.6333	1007
Augusto Severo	Brazil	SBNT	1.0000	-5.9000	35.2333	4703
Ascension AUX AF	British Terr	FHAW	1.0000	-7.9667	14.4000	3884
Diego Garcia	British Terr	FJDG	0.7262	-7.3167	-72.4167	3373
Burgas	Bulgaria	LBBG	0.3245	42.5667	-27.5000	494
Constanta	Bulgaria	LRCK	0.3166	44.3500	-28.4833	542
Libreville/Leon MBA	Gabon	FOOL	1.0504	0.4667	9.4167	3310
Kotoka Intl	Ghana	DGAA	1.0110	5.6000	0.1667	2710
Moi Intl	Kenya	HKMO	0.5275	-4.0333	-39.6000	2473
Ali Al Salem AB	Kuwait	OKAS	0.2944	29.3500	-47.5333	761
Kuwait Intl	Kuwait	OKBK	0.1652	29.2167	-47.9667	784
Hosea Kutako	Namibia	FYWH	0.9711	-22.4747	-17.4692	3710
Seeb Intl	Oman	OOMS	0.0928	23.5833	-58.2667	1425
Thumrait	Oman	OOTH	0.1122	17.6667	-54.0167	1520
Clark AB	Philippines	RPLC	0.8250	15.1833	-120.5500	4627
Mactan Intl	Philippines	RPMT	0.8981	10.3167	-123.9833	4961
Roosevelt Roads nas	Puerto Rico	TJNR	1.0000	18.2333	65.6333	5252
Al Udeid	Qatar	OTBH	0.1871	25.1170	-51.3090	1081
Dakar/Yoff	enegal (Leopol	GOOY	1.0905	14.7500	17.5000	3106
Singapore Changi	Singapore	WSSS	0.7292	1.3500	-103.9833	4331
Singapore Paya Lebar	Singapore	WSAP	0.7288	1.3500	-103.9000	4327
U-Tapao	Thailand	VTBU	0.6070	12.6667	-101.0000	3780
Entebbe	Uganda	HUEN	0.8315	0.0333	-32.4333	2224
Lusaka Intl	Zambia	FLLS	0.8505	-15.3333	-28.4500	3165
European En Routes						
Moron AB	Spain	LEMO	0.5925	37.1717	5.6095	1948
Rota NS	Spain	LERT	0.6016	36.6500	6.3500	1990
Spangdahlem AB	Germany	EDAD	0.4476	49.9667	-6.6833	1459
Mildenhall	England	EGUN	0.5816	52.3500	0.4833	1761
Fairford RAF	England	EGVA	0.5095	51.6833	1.7833	1796
Ramstein AB	Germany	EDAR	0.4410	49.4333	-7.6000	1415
Incirlik CDI	Turkey	LTAG	0.2000	37.0000	-35.4167	0
Sigonella	Italy	LICZ	0.3989	37.4000	-14.9167	978
Lajes	Potugal	LPLA	0.7839	38.7667	27.1000	2903
Pacific En Routes						
Hickam AFB	Hawaii	PHIK	1.0000	21.3167	157.9167	7221
Elmendorf AFB	Alaska	PAED	1.0000	61.2500	149.7833	4900
Andersen AFB	Guam	PGUA	1.0000	13.5833	-144.9167	5806
Misawa NAF	Japan	RJSM	0.9612	40.7000	-141.3833	4617
Yokota AB	Japan	RJTY	0.8964	35.7500	-139.3500	4723
Kadena AB	Japan	RODN	0.7717	26.3500	-127.7667	4575
Iwakuni MCAS	Japan	RJOI	0.8459	34.1500	-132.2333	4498

Figure 5. Global En Route Spreadsheet Tool (GERST)

In the GERST pictured above, the first two rows provide the drop down menus for selecting the goals and the weights associated with all six factors. Initially, the origin and destination airfields can be chosen in the first two boxes. In the other menus included on the first row, the target associated with each factor can be input. On the second row, the weights associated with each factor can be chosen. The last box provides the sum of the weight values. This sum should equal one if the weights are input correctly. In the six rows following the drop down menus, definitions of the chosen values are presented. In the rest of the spreadsheet, each en route and its associated factors values are presented. In the fourth column the *Q* value obtained by the en route contained in each row is presented. These *Q* values can then be used for further analysis if desired.

IV. Results and Analysis

Introduction

Given the large number of potential airfields considered, and the vast geographic area that they encompass, the analysis was conducted in three different sets. These sets consist of potential destinations located to the West of CONUS, to the East of CONUS, and then a combination of these two sets. The destination of Bahia Blanca, located in Argentina, does not lay to the east or west of CONUS but is analyzed as though it is located to the West of CONUS to balance the number of destinations in the easterly and westerly directions. Within each of these sets, all eight destinations were analyzed individually. A mean *Q* value for the potential en routes was obtained using each of the ten defined origins. By examining the resulting *Q* values, an assessment of beneficial potential additions to the en route system was obtained.

Destinations West of CONUS

The specific country destinations chosen to study that are near or contained to the West of CONUS include:

1) Southern South America: Argentina

2) Southern Asia: India

3) Southeastern Asia: Indonesia

4) Northeastern Asia: South Korea

Each of these destinations was studied separately to determine which of the potential en routes could provide the most benefit to the current en route system. The analysis of each particular airfield follows.

Destination 1: Southern South America

Figure 6 shows the great circle paths from all potential en route airfields included in the study to Southern South America and the specific destination of Bahia Blanca, Argentina.

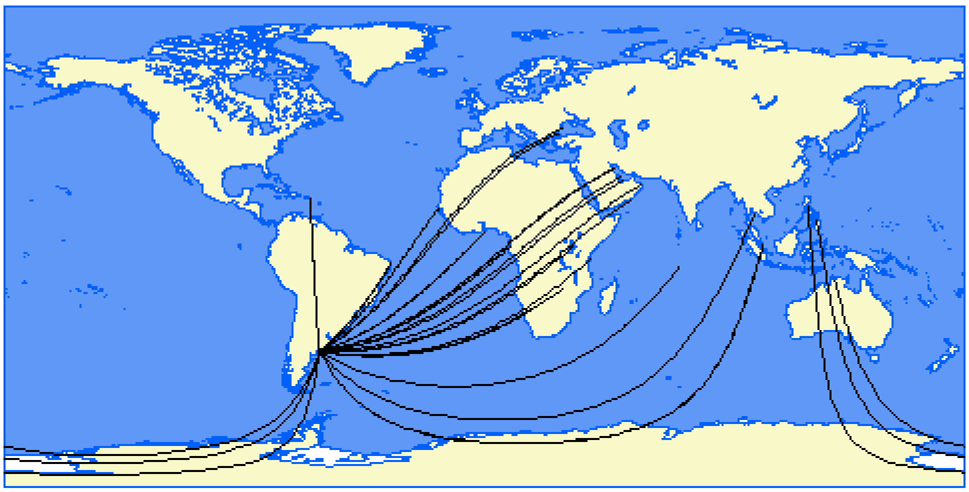


Figure 6. Great Circle Paths to South America Destination (Bahia Blanca, Argentina)

The goal program results and *Q* values for each potential en route destination is provided in Table 3. Upon initial inspection, it is apparent that Roosevelt Roads achieves the best *Q* value compared to the other potential en routes. Recall, lower *Q* scores are preferred by model construction. In fact, the Roosevelt Roads airfield also has a *Q* value that is lower than all of the current en routes. The main reason for the lower score primarily rests in the location of this destination. That is, Bahia Blanca is located in the southern South America country of Argentina. As dicussed earlier, all of the current en route airfields are located in either Europe or in the Pacific Ocean.

Table 3. Goal Program Results for Destination 1: Southern South America

Potential En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Roosevelt Roads nas	Puerto Rico	1.0000	1.0000	1.0000	0.1583	0.1664	0.2146	0.1970	0.1751	0.1686	1.0000	0.5080	1
Ascension AUX AF	British Terr	1.0000	1.0000	1.0000	1.0000	1.0000	0.2335	0.1116	0.0914	0.0859	0.0812	0.5604	2
Augusto Severo	Brazil	1.0000	1.0000	1.0000	1.0000	0.4201	0.3310	0.2507	0.2557	0.2829	0.3020	0.5842	3
Libreville/Leon MBA	Gabon	1.0000	1.0000	1.0000	1.0000	1.0000	0.3712	0.3054	0.2816	0.2405	0.2210	0.6420	4
Dakar/Yoff	Senegal (Leopold)	1.0000	1.0000	1.0000	1.0000	1.0000	0.4004	0.3794	0.3534	0.3086	0.2873	0.6729	5
Kotoka Intl	Ghana	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.4446	0.4168	0.3690	0.3464	0.7577	6
Burgas	Bulgaria	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.3534	0.2775	0.2415	0.7872	7
Hosea Kutako	Namibia	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.3254	0.2954	0.2588	0.7880	8
Constanta	Bulgaria	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.2831	0.2467	0.8530	9
Bahrain Intl	Bahrain	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.2202	0.9220	10
Moi Intl	Kenya	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.2581	0.9258	11
Kuwait Intl	Kuwait	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.3016	0.9302	12
Lusaka Intl	Zambia	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.3338	0.9334	13
Al Udeid	Qatar	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.3450	0.9345	14
Ali Al Salem AB	Kuwait	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.4257	0.9426	15
Entebbe	Uganda	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.5266	0.9527	16
Darwin Intl	Australia	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	17
Diego Garcia	British Terr	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	17
Seeb Intl	Oman	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	17
Thumrait	Oman	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	17
Clark AB	Philippines	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	17
Mactan Intl	Philippines	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	17
Singapore Changi	Singapore	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	17
Singapore Paya Lebar	Singapore	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	17
U-Tapao	Thailand	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	17

European En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Lajes	Potugal	1.0000	1.0000	1.0000	1.0000	1.0000	0.2390	0.2131	0.1809	0.1254	0.0992	0.5857	1
Rota NS	Spain	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.2350	0.2000	0.1397	0.1111	0.6686	2
Moron AB	Spain	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.2387	0.2034	0.1426	0.1138	0.6699	3
Sigonella	Italy	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.2957	0.2558	0.1871	0.1545	0.6893	4
Fairford RAF	England	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.2986	0.2585	0.1894	0.1566	0.6903	5
Spangdahlem AB	Germany	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.3117	0.2705	0.1996	0.1660	0.6948	6
Ramstein AB	Germany	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.3122	0.2710	0.2000	0.1664	0.6950	7
Mildenhall	England	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.3869	0.3464	0.2765	0.2435	0.7253	8
Incirlik CDI	Turkey	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.2367	0.2000	0.8437	9

Pacific En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Elmendorf AFB	Alaska	1.0000	1.0000	1.0000	0.2539	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9254	1
Hickam AFB	Hawaii	1.0000	1.0000	0.2734	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9273	2
Andersen AFB	Guam	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	3
Misawa NAF	Japan	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	3
Yokota AB	Japan	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	3
Kadena AB	Japan	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	3
Iwakuni MCAS	Japan	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	3

Figure 7 gives a graphical representation of all potential en route and current en route mean *Q* values to the destination Southern South America. These *Q* values are taken from the column labeled "Mean Value" as listed in Table 3 which are the averages for all of the chosen origins to this particular destination. This chart is an alternate representation that shows Roosevelt Roads is the best possible en route airfield given the factors modeled in the goal program based scoring technique.

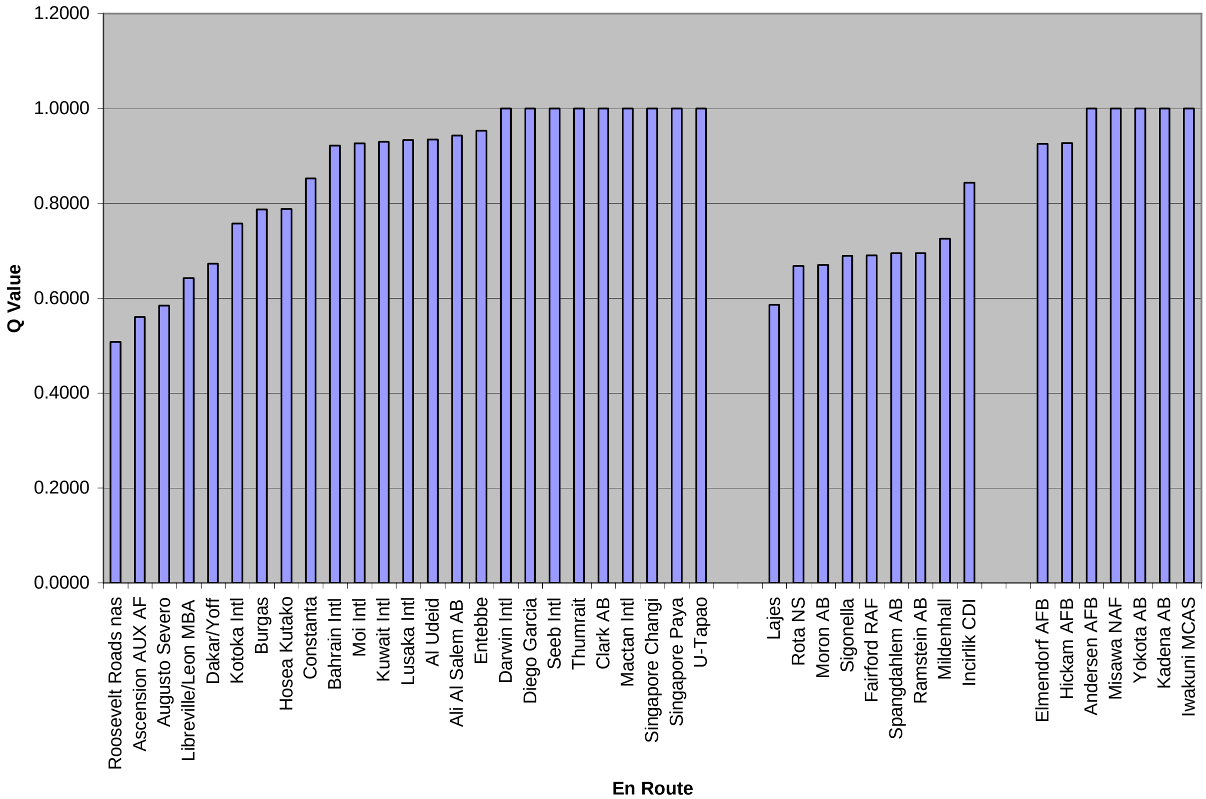


Figure 7. Mean *Q* Values for Destination 1: Southern South America

In summary, of the potential en route airfields included in this model, Roosevelt Roads, Ascension, and Augusto Severo are the best potential en routes to support strategic airlift to this destination.

Destination 2: Southern Asia

Figure 8 shows the great circle paths from all potential en route airfields included in the study to Southern Asia and the specific destination of Gao, India.

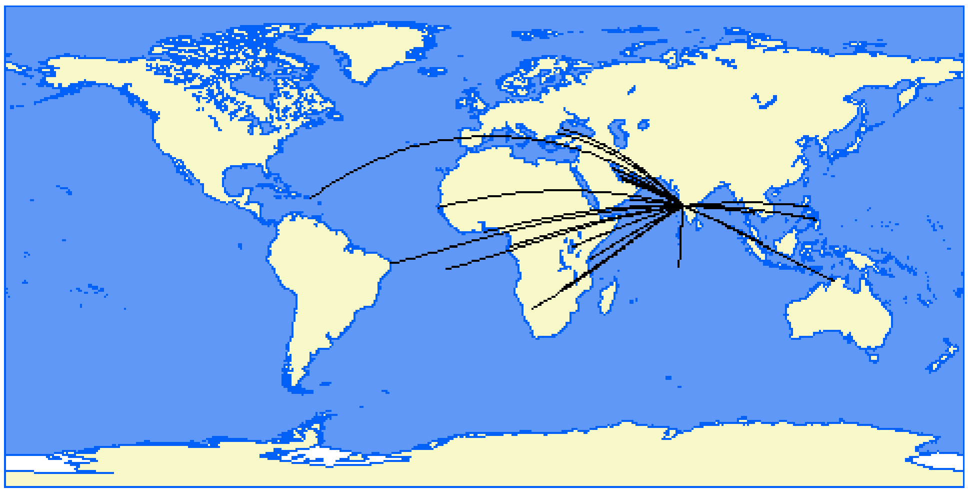


Figure 8. Great Circle Paths to Southern Asia Destination (Gao, India)

Given the airfield located in India as a destination, several potential en route airfields stand out as good alternatives. As shown in Table 4, the top nine average *Q* values achieved by the potential en routes all standout. These nine potential en route *Q* values were all calculated to be between 0.16 and 0.43. In fact, the average values for the top three potential en routes of Seeb International, Bahrain International, and Kuwait International are all lower than that of any current en route. In examining Table 4, traveling from any of the origins represented in the model to Gao airfield in India, Seeb International airport represents the only en route location where the total distance traveled never exceeds 8,500 nm. For all other existing or potential en routes in this model, the total distance traveled is over 8,500 nm from at least one origin to Gao, india. The fact that this airfield was never penalized a single time due to excessive route distance enabled it to achieve the lowest average *Q* value in the model. If this potential en route had been penalized because of route distance, it would have scored worse compared to alternate airfields. For example, if it had achieved a *Q* value of one from the Incirlik origin to Gao, India, its resulting average *Q* score would have been 0.2596 which would rank it second among all potential en route airfields in the model.

Table 4. Goal Program Results for Destination 2: Southern Asia

Potential En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Seeb Intl	Oman	0.2535	0.2764	0.2190	0.1844	0.1800	0.1507	0.1251	0.1082	0.0986	0.0359	0.1632	1
Bahrain Intl	Bahrain	0.2827	0.3124	1.0000	0.1792	0.1702	0.1294	0.0924	0.0680	0.0560	0.0404	0.2330	2
Kuwait Intl	Kuwait	0.3686	0.4047	1.0000	0.2519	0.2431	0.1999	0.1597	0.1327	0.1155	0.1569	0.3033	3
U-Tapao	Thailand	0.1010	0.0800	0.1559	0.1968	0.2010	1.0000	0.3242	0.3550	0.3551	0.4562	0.3225	4
Thumrait	Oman	0.2960	0.3064	1.0000	0.2120	1.0000	0.1586	0.1260	0.1063	0.1103	0.0515	0.3367	5
Constanta	Bulgaria	0.3608	1.0000	1.0000	0.1602	0.1497	0.0935	0.0663	0.1122	0.1544	0.3261	0.3423	6
Al Udeid	Qatar	0.4083	0.4355	1.0000	0.3084	0.2991	0.2587	0.2225	0.1988	0.1890	0.1556	0.3476	7
Ali Al Salem AB	Kuwait	0.4952	0.5316	1.0000	0.3766	0.3675	0.3238	0.2829	0.2555	0.2382	0.2858	0.4157	8
Burgas	Bulgaria	0.3718	1.0000	1.0000	0.1676	1.0000	0.0953	0.0664	0.1123	0.1545	0.3263	0.4294	9
Singapore Changi	Singapore	0.1492	0.0864	0.1702	0.2420	1.0000	1.0000	1.0000	0.4156	0.4308	0.5563	0.5050	10
Singapore Paya Lebar	Singapore	0.1500	0.0873	0.1709	0.2426	1.0000	1.0000	1.0000	0.4157	0.4309	0.5561	0.5053	11
Clark AB	Philippines	0.1677	0.1371	0.1365	0.1939	1.0000	1.0000	1.0000	1.0000	0.4628	0.6404	0.5738	12
Mactan Intl	Philippines	0.1988	0.1654	0.1357	0.2092	1.0000	1.0000	1.0000	1.0000	1.0000	0.7002	0.6409	13
Diego Garcia	British Terr	0.5290	0.4707	1.0000	0.5241	1.0000	1.0000	0.4934	0.5007	0.5398	0.5916	0.6649	14
Moi Intl	Kenya	0.5823	1.0000	1.0000	1.0000	1.0000	1.0000	0.2658	0.2516	0.3111	0.3380	0.6749	15
Darwin Intl	Australia	0.3095	0.2666	0.1639	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.7740	16
Lusaka Intl	Zambia	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.3959	0.3941	0.4854	0.5974	0.7873	17
Hosea Kutako	Namibia	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.3600	0.3917	0.4857	0.6902	0.7928	18
Entebbe	Uganda	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.5083	0.4877	0.5490	0.6410	0.8186	19
Libreville/Leon MBA	Gabon	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.3853	0.4651	0.5385	0.8370	0.8226	20
Kotoka Intl	Ghana	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.4296	0.4997	0.5640	0.8259	0.8319	21
Dakar/Yoff	Senegal (Leopold)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.4502	0.5339	0.6109	0.9237	0.8519	22
Ascension AUX AF	British Terr	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.2684	0.3550	1.0000	1.0000	0.8623	23
Augusto Severo	Brazil	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	24
Roosevelt Roads nas	Puerto Rico	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	24

European En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Incirlik CDI	Turkey	0.3131	0.3649	1.0000	0.1405	1.0000	0.0731	0.0183	0.0203	0.0558	0.2000	0.3186	1
Sigonella	Italy	1.0000	1.0000	1.0000	0.1359	1.0000	0.0287	0.0535	0.1073	0.1568	0.3580	0.4840	2
Ramstein AB	Germany	1.0000	1.0000	1.0000	0.0829	1.0000	0.0128	0.0842	0.1445	0.2000	0.4256	0.4950	3
Spangdahlem AB	Germany	1.0000	1.0000	1.0000	0.0802	1.0000	0.0150	0.0872	0.1481	0.2042	0.4321	0.4967	4
Fairford RAF	England	1.0000	1.0000	1.0000	0.0882	1.0000	0.0335	0.1118	0.1780	0.2389	0.4863	0.5137	5
Mildenhall	England	1.0000	1.0000	1.0000	0.1683	1.0000	0.1142	0.1917	0.2571	0.3173	0.5620	0.5610	6
Moron AB	Spain	1.0000	1.0000	1.0000	1.0000	1.0000	0.0448	0.1270	0.1965	0.2603	0.5198	0.6148	7
Rota NS	Spain	1.0000	1.0000	1.0000	1.0000	1.0000	0.0470	0.1300	0.2000	0.2644	0.5263	0.6168	8
Lajes	Potugal	1.0000	1.0000	1.0000	1.0000	1.0000	0.1125	0.2131	0.2980	0.3760	0.6935	0.6693	9

Pacific En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Kadena AB	Japan	0.1658	0.1309	0.0611	0.0968	0.1158	1.0000	1.0000	1.0000	0.3873	0.5891	0.4547	1
Iwakuni MCAS	Japan	0.2834	0.2456	0.1331	0.1531	0.1798	1.0000	1.0000	1.0000	0.4494	0.6664	0.5111	2
Yokota AB	Japan	0.3261	0.2843	0.1352	0.1820	0.1661	1.0000	1.0000	1.0000	1.0000	0.7079	0.5802	3
Misawa NAF	Japan	0.4243	0.3814	0.2280	0.2761	0.2395	1.0000	1.0000	1.0000	1.0000	0.7770	0.6326	4
Andersen AFB	Guam	0.2945	0.2479	0.0814	0.1336	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.6757	5
Elmendorf AFB	Alaska	1.0000	1.0000	0.1808	0.2539	0.1624	1.0000	1.0000	1.0000	1.0000	1.0000	0.7597	6
Hickam AFB	Hawaii	1.0000	1.0000	0.2734	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9273	7

A bar chart of the *Q* values for all possible en routes with a destination of Southern Asia (Figure 9) presents the model results more simply. In this figure, it is clear that the three best potential en route airfields have a lower *Q* value than that of any current ones. Again, the three potential en routes that scored extremely well were Seeb International, Bahrain International, and Kuwait International. These airfields achieved *Q* scores of 0.1632, 0.2330, and 0.3033 respectively. These values are all lower than 0.3186 which was the best *Q* value achieved by any current en route airfield.

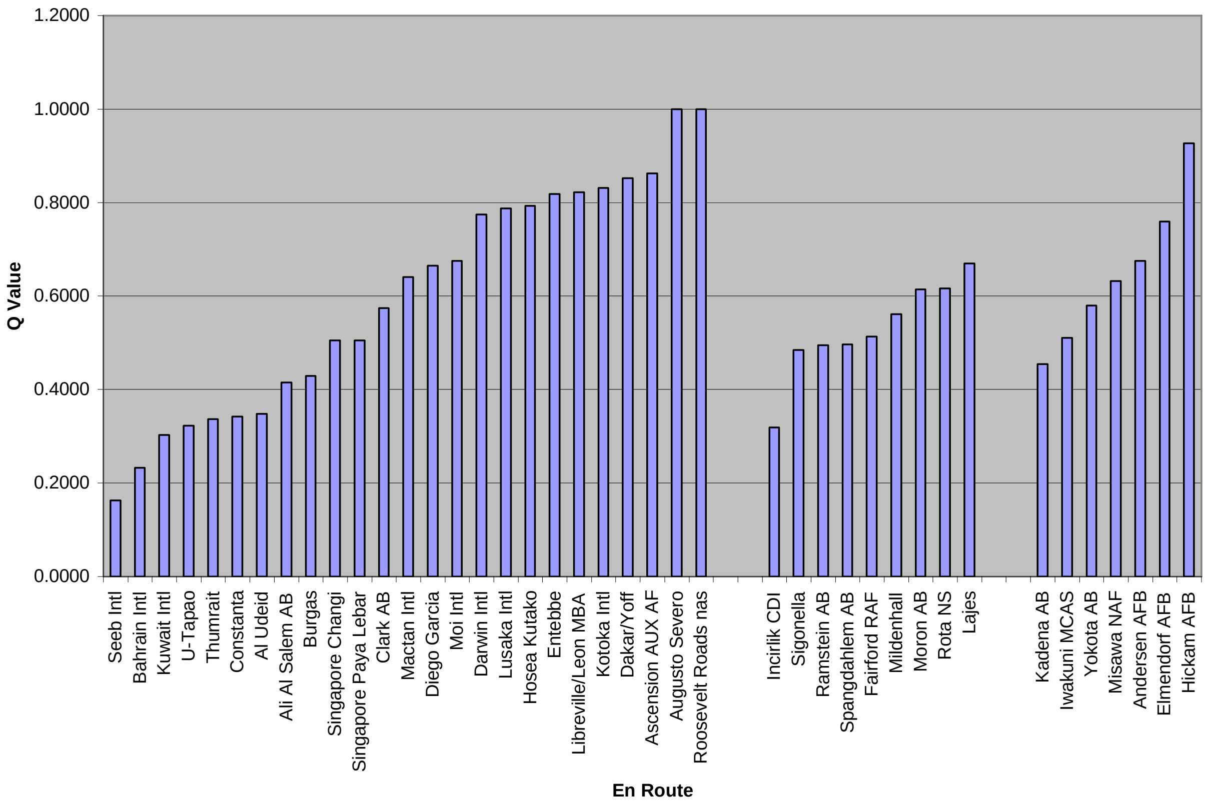


Figure 9. Mean *Q* Values for Destination 2: Southern Asia

In summary, of the potential en route airfields included in this model, Seeb International, Bahrain International, and Kuwait International are the best potential en routes to support strategic airlift to this destination.

Destination 3: Northeast Asia

Figure 10 shows the great circle paths from all potential en route airfields included in the study to Northeast Asia and the specific destination of Seoul AB, Republic of Korea.

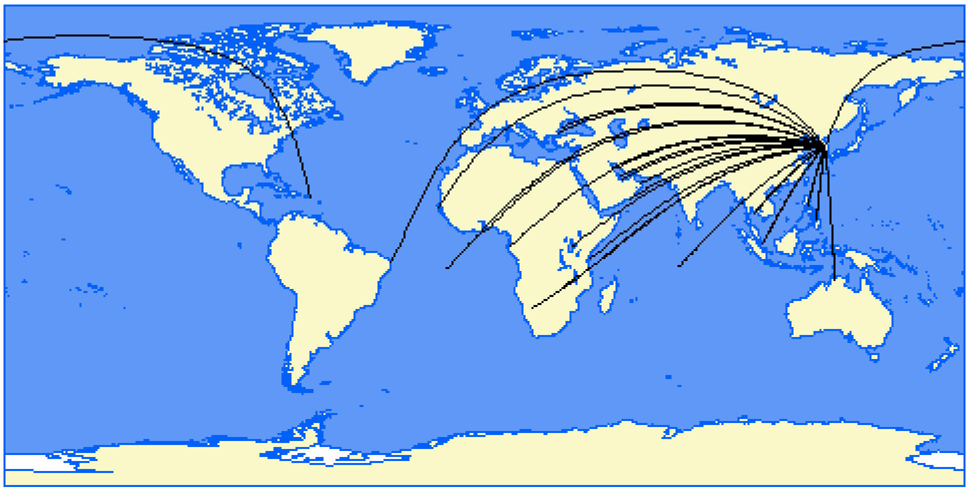


Figure 10. Great Circle Paths to Northeast Asia Destination (Seoul AB, Republic of Korea)

While the previous destinations studied contained several potential en route airfields that had *Q* scores comparable to many of the existing en routes, this destination did not. Since this destination is located to the West of CONUS, the existing Pacific en route airfields are expected to achieve the best scores here. The Pacific en routes achieve *Q* scores between 0.2505 and 0.641 to this destination and they are certainly the best values achieved in the model when flying to Northeast Asia. For the potential en route airfields, however, Clark AB and Mactan International in the Philippenes as well as U-Tapao in Thailand produced *Q* scores that are similar to the best five Pacific en route airfields. The *Q* scores achieved for these three airfields were 0.411, 0.5041, and 0.5552 respectively. Even though this destination is difficult to reach, some of the potential en route airfields are able to achieve *Q* scores that were close to or better than the existing en routes. The *Q* scores achieved by the existing and potential en route airfields is shown in Table 5.

Table 5. Goal Program Results for Destination 3: Northeast Asia

Potential En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Clark AB	Philippines		0.2048	0.3430	0.4351	0.3714	1.0000	0.3463	0.3325	0.3494	0.3172	0.4111	1
Mactan Intl	Philippines		0.2598	0.3379	0.4586	0.3806	1.0000	1.0000	0.3618	0.3842	0.3537	0.5041	2
U-Tapao	Thailand		0.4271	0.4124	0.4736	1.0000	1.0000	1.0000	0.2372	0.2540	0.1922	0.5552	3
Seeb Intl	Oman		0.9394	1.0000	1.0000	1.0000	1.0000	0.0877	0.0528	0.1056	0.1421	0.5920	4
Bahrain Intl	Bahrain		1.0000	1.0000	1.0000	1.0000	1.0000	0.0588	0.0722	0.1290	0.1684	0.6031	5
Thumrait	Oman		1.0000	1.0000	1.0000	1.0000	1.0000	0.0885	0.0805	0.1390	0.1796	0.6097	6
Constanta	Bulgaria		1.0000	1.0000	1.0000	1.0000	1.0000	0.1300	0.1474	0.2095	0.2526	0.6377	7
Kuwait Intl	Kuwait		1.0000	1.0000	1.0000	1.0000	1.0000	0.1417	0.1577	0.2150	0.2547	0.6410	8
Burgas	Bulgaria		1.0000	1.0000	1.0000	1.0000	1.0000	0.1364	0.1542	0.2177	0.2617	0.6411	9
Al Udeid	Qatar		1.0000	1.0000	1.0000	1.0000	1.0000	0.1883	0.1975	0.2544	0.2938	0.6593	10
Singapore Changi	Singapore		0.4300	0.4309	0.5461	1.0000	1.0000	1.0000	1.0000	0.3168	0.2538	0.6642	11
Singapore Paya Lebar	Singapore		0.4316	0.4318	0.5468	1.0000	1.0000	1.0000	1.0000	0.3170	0.2539	0.6646	12
Ali Al Salem AB	Kuwait		1.0000	1.0000	1.0000	1.0000	1.0000	0.2677	0.2838	0.3413	0.3812	0.6971	13
Darwin Intl	Australia		0.5971	0.3723	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8855	14
Diego Garcia	British Terr		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.4224	0.9358	15
Moi Intl	Kenya		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.4480	0.9387	16
Entebbe	Uganda		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.7451	0.9717	17
Augusto Severo	Brazil		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	18
Ascension AUX AF	British Terr		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	18
Libreville/Leon MBA	Gabon		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	18
Kotoka Intl	Ghana		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	18
Hosea Kutako	Namibia		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	18
Roosevelt Roads nas	Puerto Rico		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	18
Dakar/Yoff	Senegal (Leopold)		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	18
Lusaka Intl	Zambia		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	18

European En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Ramstein AB	Germany		1.0000	1.0000	1.0000	1.0000	0.1100	0.1115	0.1309	0.2000	0.2479	0.5334	1
Spangdahlem AB	Germany		1.0000	1.0000	1.0000	1.0000	0.1101	0.1117	0.1311	0.2002	0.2481	0.5335	2
Fairford RAF	England		1.0000	1.0000	1.0000	1.0000	0.1191	0.1208	0.1407	0.2118	0.2611	0.5393	3
Mildenhall	England		1.0000	1.0000	1.0000	1.0000	0.1984	0.2000	0.2197	0.2899	0.3386	0.5830	4
Incirlik CDI	Turkey		1.0000	1.0000	1.0000	1.0000	1.0000	0.0782	0.0955	0.1572	0.2000	0.6146	5
Sigonella	Italy		1.0000	1.0000	1.0000	1.0000	1.0000	0.1293	0.1498	0.2228	0.2734	0.6417	6
Moron AB	Spain		1.0000	1.0000	1.0000	1.0000	1.0000	0.1735	0.1967	0.2796	0.3370	0.6652	7
Lajes	Potugal		1.0000	1.0000	1.0000	1.0000	0.2110	0.2131	0.2379	0.3266	1.0000	0.6654	8
Rota NS	Spain		1.0000	1.0000	1.0000	1.0000	1.0000	0.1766	0.2000	0.2835	0.3414	0.6668	9

Pacific En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Elmendorf AFB	Alaska		0.7802	0.1869	0.2539	0.1230	0.0709	0.1323	0.1833	0.2016	0.3226	0.2505	1
Kadena AB	Japan		0.1185	0.2417	0.2970	0.2667	0.2730	0.2742	0.2714	0.2803	0.2696	0.2547	2
Yokota AB	Japan		0.2434	0.2676	0.2935	0.2938	0.3175	0.3431	0.3540	0.3603	0.3780	0.3168	3
Iwakuni MCAS	Japan		0.2509	0.2997	0.3238	0.3170	0.3286	0.3396	0.3433	0.3478	0.3522	0.3225	4
Misawa NAF	Japan		0.3939	0.3442	0.3445	0.3600	0.3839	0.4115	0.4250	0.4288	0.4545	0.3940	5
Andersen AFB	Guam		0.2479	0.1819	0.3335	0.2620	1.0000	1.0000	1.0000	0.3945	0.4033	0.5359	6
Hickam AFB	Hawaii		0.7897	0.2734	0.3538	0.1967	0.1558	1.0000	1.0000	1.0000	1.0000	0.6410	7

The bar chart of the average *Q* values calculated for the current and potential en route airfields is shown in Figure 11. The most apparent result from this particular study is the difficulty associated with the distance to this destination. As can be seen in Table 5, the primary airfields receiving good *Q* values to this destination are Clark AB and Mactan International in the Philippines and U-Tapao in Thailand. While these airfields are located fairly close to the Northeastern Asia destination, their location with respect to the given origins are somewhat distant. This long critical leg distance causes all of the potential en route airfields to receive somewhat poor *Q* values. While the critical leg distance is not the only factor included in the *Q* value determination, it is the only factor that provides the current or potential en route with a different *Q* value for each destination considered. Another important result obtained in the study of this particular destination is that Seeb International receives a *Q* value that ranks fourth among all potential en route airfields studied. This is important because this destination is clearly located to the East of CONUS while Seeb International is located to the west of CONUS in the country of Oman.

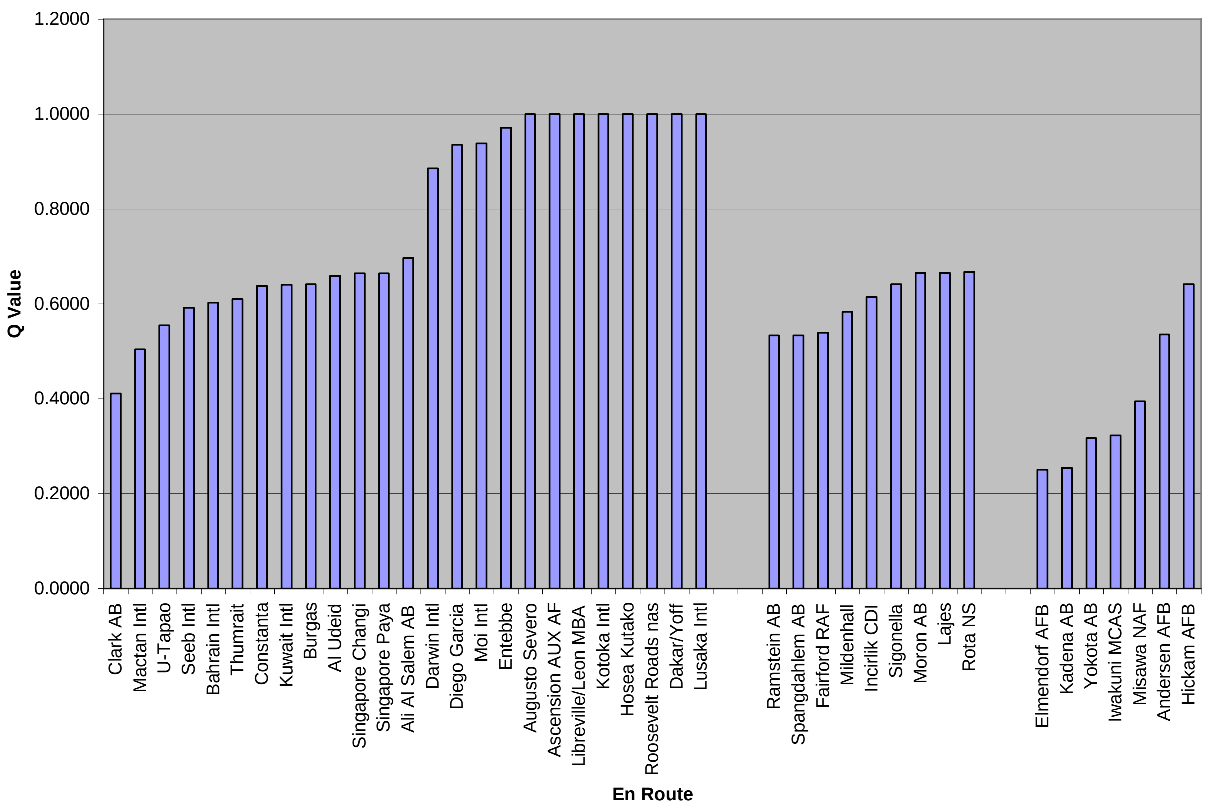


Figure 11. Mean *Q* Values for Destination 3: Northeastern Asia

In summary, of the potential en route airfields included in this model, Clark AB, Mactan International, and U-Tapao are the best potential en routes to support strategic airlift to this destination. It is also noted that Seeb International ranks closely behind these airfields with an average Q value of 0.5920.

Destination 4: Southeast Asia

Figure 12 shows the great circle paths from all potential en route airfields included in the study to Southeast Asia and the specific destination of Dili, Indonesia.

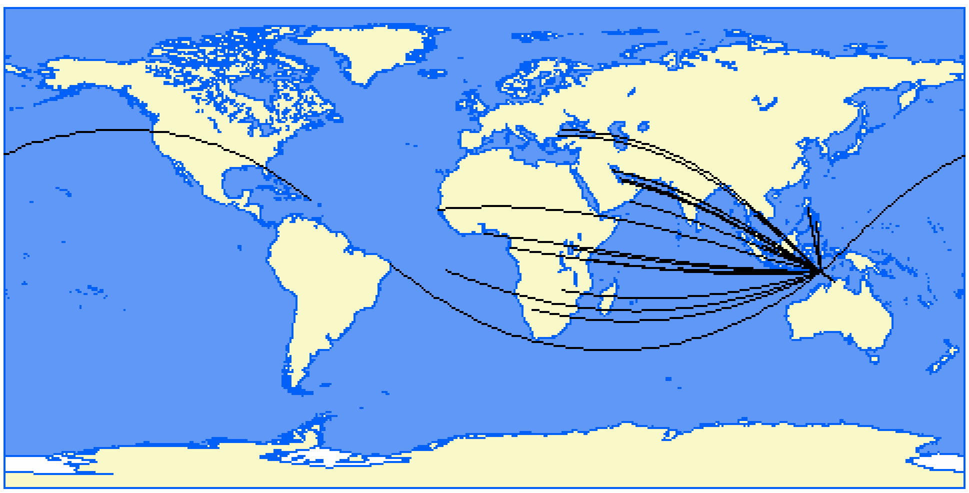


Figure 12. Great Circle Paths to Southeast Asia Destination (Dili, Indonesia)

The final destination studied located to the west of CONUS was Southeastern Asia as represented by Dili, Indonesia. Using this airfield as a destination location, some interesting average Q values were achieved. These numerical values are summarized in Table 6. The average Q values were all very similar to those achieved when routing to Northeast Asia. This is to be expected because the destinations chosen to represent these two destinations, Seoul AB, Republic of Korea and Dili, India, are relatively close to each other. Given the proximity of the destinations, the three best Q values achieved by the potential airfields are in the same order.

Again, Clark AB, Mactan International, and U-Tapao receive the first second and third best scores respectively. After the top three airfields, Darwin, Changi, Paya Lebar, and Bahrain International are each rank ordered somewhat differently due to the changed critical leg distance to this destination.

Table 6. Goal Program Results for Destination 4: Southeast Asia

Potential En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Clark AB	Philippines	0.1047	0.2051	0.2551	0.1972	0.2317	1.0000	1.0000	0.2115	0.1983	0.1986	0.3602	1
Mactan Intl	Philippines	0.1304	0.1618	0.2518	0.2126	0.2396	1.0000	1.0000	0.2343	0.2234	0.2264	0.3680	2
U-Tapao	Thailand	0.1901	0.4132	0.3032	0.2006	1.0000	1.0000	1.0000	0.1298	0.1192	0.0953	0.4451	3
Darwin Intl	Australia	0.3224	0.3016	0.2836	0.3031	0.2929	1.0000	1.0000	0.3197	0.3215	0.3268	0.4472	4
Singapore Changi	Singapore	0.2511	0.4163	0.3200	0.2461	1.0000	1.0000	1.0000	0.1682	0.1649	0.1427	0.4709	5
Singapore Paya Lebar	Singapore	0.2520	0.4178	0.3208	0.2467	1.0000	1.0000	1.0000	0.1684	0.1651	0.1429	0.4714	6
Seeb Intl	Oman	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0281	0.0554	0.1070	0.7190	7
Thumrait	Oman	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0350	0.0631	0.1163	0.7214	8
Bahrain Intl	Bahrain	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0511	0.0812	0.1381	0.7270	9
Kuwait Intl	Kuwait	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1438	0.1751	0.2341	0.7553	10
Diego Garcia	British Terr	0.6922	1.0552	1.0000	1.0000	1.0000	1.0000	1.0000	0.3000	0.3120	0.2695	0.7629	11
Al Udeid	Qatar	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1734	0.2032	0.2594	0.7636	12
Constanta	Bulgaria	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1651	0.2029	0.2742	0.7642	13
Burgas	Bulgaria	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1672	0.2053	0.2771	0.7650	14
Ali Al Salem AB	Kuwait	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.2701	0.3015	0.3607	0.7932	15
Moi Intl	Kenya	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.2874	0.9287	16
Entebbe	Uganda	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.5983	0.9598	17
Augusto Severo	Brazil	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	18
Ascension AUX AF	British Terr	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	18
Libreville/Leon MBA	Gabon	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	18
Kotoka Intl	Ghana	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	18
Hosea Kutako	Namibia	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	18
Roosevelt Roads nas	Puerto Rico	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	18
Dakar/Yoff	Senegal (Leopold)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	18
Lusaka Intl	Zambia	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	18

European En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Ramstein AB	Germany	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1246	0.1572	0.2000	0.2808	0.6763	1
Spangdahlem AB	Germany	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1258	0.1584	0.2014	0.2826	0.6768	2
Incirlik CDI	Turkey	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0971	0.1327	0.2000	0.7430	3
Fairford RAF	England	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1381	0.1720	0.2166	1.0000	0.7527	4
Sigonella	Italy	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1480	0.1897	0.2685	0.7606	5
Mildenhall	England	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.2186	0.2522	0.2965	1.0000	0.7767	6
Moron AB	Spain	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1977	1.0000	1.0000	0.9198	7
Rota NS	Spain	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.2000	1.0000	1.0000	0.9200	8
Lajes	Potugal	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.2131	1.0000	1.0000	1.0000	0.9213	9

Pacific En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Kadena AB	Japan	0.1348	0.3087	0.1648	0.0996	0.1445	1.0000	1.0000	0.1553	0.1376	0.1523	0.3298	1
Andersen AFB	Guam	0.1020	0.2479	0.1192	0.1273	0.1456	1.0000	1.0000	1.0000	0.2205	0.2544	0.4217	2
Iwakuni MCAS	Japan	0.2958	0.5105	0.2288	0.1532	0.2059	1.0000	1.0000	1.0000	0.2122	0.2368	0.4843	3
Yokota AB	Japan	0.3261	0.5557	0.2035	0.1375	0.1904	1.0000	1.0000	1.0000	0.2221	0.2568	0.4892	4
Misawa NAF	Japan	0.4579	0.7134	0.2820	0.2293	0.2624	1.0000	1.0000	1.0000	0.2964	0.3361	0.5578	5
Hickam AFB	Hawaii	0.5733	0.9751	0.2734	0.2137	0.1594	1.0000	1.0000	1.0000	1.0000	1.0000	0.7195	6
Elmendorf AFB	Alaska	1.0000	1.0000	0.3240	0.2539	0.1901	1.0000	1.0000	1.0000	1.0000	1.0000	0.7768	7

The order of the *Q* values mentioned previously can be seen more clearly in Figure 13. While the location of this particular destination is close in proximity to the one located in Northeast Asia, the *Q* scores achieved to this destination by the potential en route airfields were much better here. Concurrently, the *Q* scores received by the existing Pacific en route airfields were worse. For the potential en routes, the *Q* score range for the best three airfields to the Northeast Asia destination was between 0.411 and 0.552. To the Southeast Asia destination the same three potential en route airfields achieved *Q* scores between 0.3602 and 0.4451. While the potential en route airfield *Q* scores decreased, the existing Pacific en route *Q* scores increased. To the Northeast Asia destination the top three Pacific en route *Q* scores ranged from 0.2505 to 0.3168, while to the Southeast Asia destination their best three *Q* scores were between 0.3298 and 0.4843. Given these statistics, it is apparent that the existing Pacific en route airfields are located in areas that help them achieve better *Q* scores to Northeast Asia rather than Southeast Asia. Alternatively, the potential en route airfields appear to be located in regions that achieve better *Q* scores to the Southeast Asia destination instead of Northeast Asia. These results are to be expected due to the missions associated with the current en route airfields. Since the Pacific en route airfields are designed to support mobility operations to the destinations in Northeast Asia it is not surprising that it receives better *Q* values to the destinations in this region and worse scores to the destination in Southeast Asia.

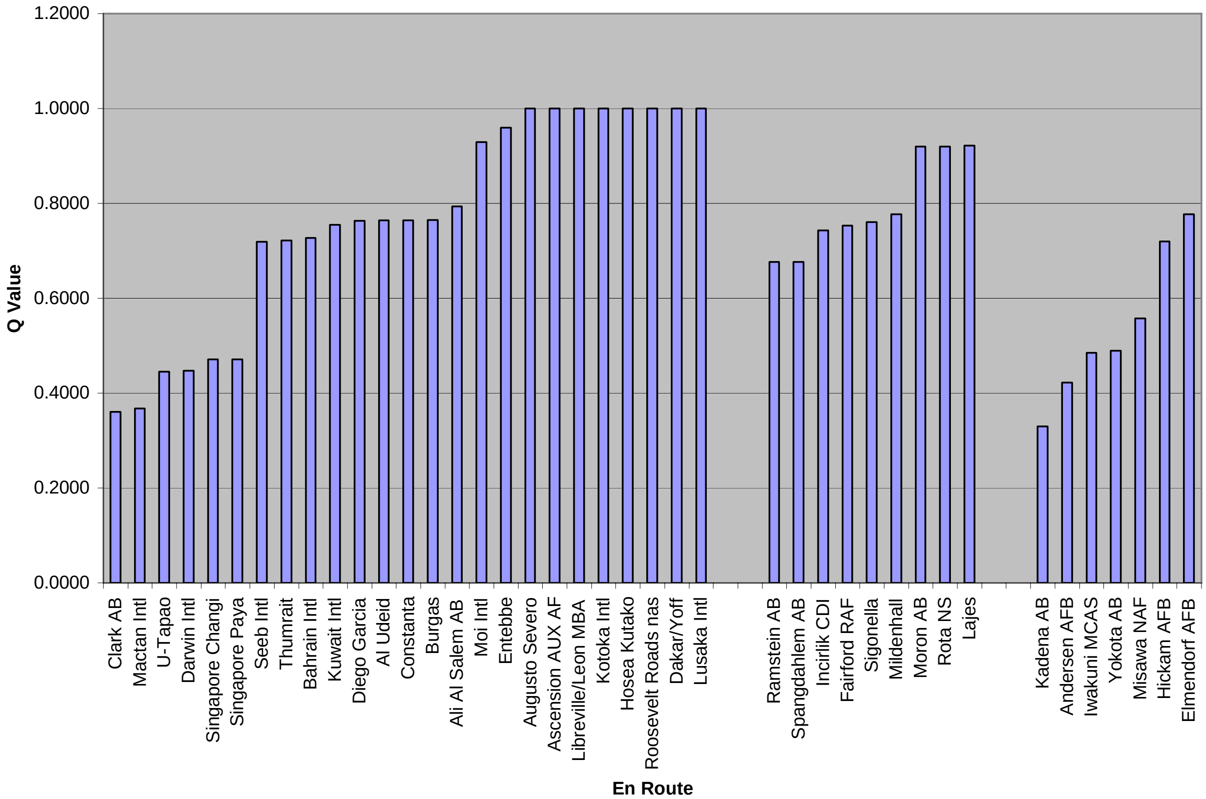


Figure 13. Mean *Q* Values for Destination 4: Southeast Asia

In summary, of the potential en route airfields included in this model, Clark AB, Mactan International, and U-Tapao are the best potential en routes to support strategic airlift to the destination in Southwest Asia.

While analyzing the destinations strictly to the west of CONUS the best three potential en route *Q* values achieved to each particular destination are presented below.

Destination 1: Southern South America: (Bahia Blanca, Argentina)

1) Roosevelt Roads NAS, Puerto Rico, *Q* = 0.5080

2) Ascension Island, British Territory, *Q* =0.5604

3) Augusto Severo, Brazil, *Q* = 0.5842

Destination 2: Southeast Asia: (Dili, Indonesia)

1) Clark AB, Philippines, Q =0.3602

2) Mactan International, Philippines, Q = 0.3680

3) U-Tapao, Thailand, Q = 0.4451

Destination 3: Northeast Asia: (Seoul International, South Korea)

1) Clark AB, Philippines, Q = 0.4111

2) Mactan International, Philippines, Q = 0.5041

3) U-Tapao, Thailand, Q = 0.5552

Destination 4: Southern Asia: (Gao, India)

1) Seeb International, Oman, Q = 0.1632

2) Bahrain International, Bahrain, Q = 2330

3) Kuwait International, Kuwait, Q = 0.3033

Destinations East of CONUS

After modeling each of the destinations to the West of the United States proposed by USTRANSCOM, destinations located to the East of CONUS are considered next. The specific country destinations chosen to study that are near or contained to the East of CONUS include

1) Southwest Asia: Iraq
2) Central Asia: Pakistan
3) Western Africa: Liberia
4) Southern Africa: South Africa

Destination 5: Southwest Asia

Figure 14 shows the great circle paths from all potential en route airfields included in the study to Southwest Asia and the specific destination of Baghdad International, Iraq.

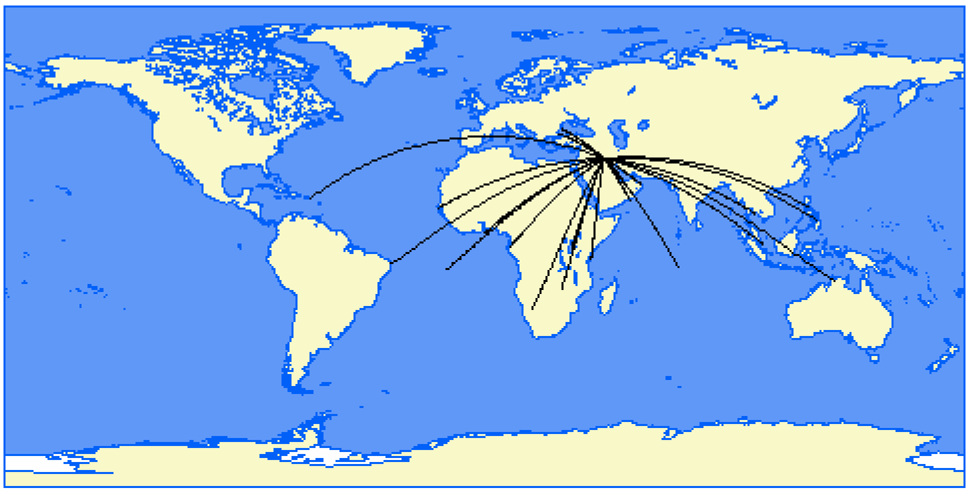


Figure 14. Great Circle Paths to Southwest Asia Destination (Baghdad International, Iraq)

The final destination studied in this area was located in the country of Iraq. The European en route airfields are currently being used to fly to this destination. Although these en routes are providing a useable stop for aircraft destined for this area, the study considers this region for the addition of future en route airfields. While Ramstein AB produces the best *Q* value when considering Baghdad International as a Southwest Asia destination, several potential airfields still receive a good *Q* value. These values do not prove that an alternate airfield would provide a better en route stop for this destination, but these values combined with alternate destination values show the potential benefit of the addition of certain airfields to the current en route system. As can be seen in Table 7 below, Constanta and Burgas in Bulgaria as well as Bahrain International in Bahrain all produce very respectable average *Q* scores when routing to this destination from all of the considered origins. While Ramstein AB receives a much better value to this destination, the critical leg distance is the main reason for its superior *Q* value calculation. Several of the other potential en route airfields contain similar values pertaining to other factors, but the useful location with respect to travel to Southwest Asia improves Ramstein AB's overall score.

Table 7. Goal Program Results for Destination 5: Southwest Asia

Potential En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Constanta	Bulgaria	0.2683	0.2811	0.2256	0.2009	0.1973	0.1756	0.1415	0.1161	0.0596		0.1851	1
Burgas	Bulgaria	0.2773	0.2876	0.2317	0.2093	0.2023	0.1779	0.1394	0.1083	0.0547		0.1876	2
Bahrain Intl	Bahrain	0.1953	0.1848	0.2115	0.2289	0.2290	0.2403	0.2589	0.2766	0.3127		0.2376	3
Seeb Intl	Oman	0.1714	0.1577	0.2048	0.2349	0.2404	0.2689	0.3102	0.3483	0.3980		0.2594	4
Kuwait Intl	Kuwait	0.2808	0.2748	0.2905	0.3003	0.3003	0.3066	0.3171	0.3268	0.3482		0.3050	5
Al Udeid	Qatar	0.3208	0.3084	0.3385	0.3588	0.3585	0.3711	0.3920	0.4120	0.4537		0.3682	6
Ali Al Salem AB	Kuwait	0.4071	0.4013	0.4157	0.4249	0.4245	0.4300	0.4393	0.4479	0.4686		0.4288	7
Thumrait	Oman	0.2062	0.1803	1.0000	0.2661	1.0000	0.2794	0.3117	0.3448	0.4215		0.4456	8
U-Tapao	Thailand	0.1265	0.0736	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8809		0.7868	9
Moi Intl	Kenya	0.4639	1.0000	1.0000	1.0000	1.0000	1.0000	0.4578	0.5031	0.6945		0.7910	10
Libreville/Leon MBA	Gabon	1.0000	1.0000	1.0000	1.0000	1.0000	0.3312	0.4340	0.5928	0.7721		0.7922	11
Kotoka Intl	Ghana	1.0000	1.0000	1.0000	1.0000	1.0000	0.4387	0.4510	0.5823	0.7305		0.8003	12
Dakar/Yoff	Senegal (Leopold)	1.0000	1.0000	1.0000	1.0000	1.0000	0.3202	0.4702	0.6251	0.7999		0.8017	13
Singapore Changi	Singapore	0.1826	0.1212	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000		0.8115	14
Singapore Paya Lebar	Singapore	0.1827	0.1214	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000		0.8116	15
Clark AB	Philippines	0.2507	0.1834	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000		0.8260	16
Mactan Intl	Philippines	0.2840	0.2115	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000		0.8328	17
Ascension AUX AF	British Terr	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.3505	0.5337	0.7405		0.8472	18
Diego Garcia	British Terr	0.4393	0.3617	1.0000	1.0000	1.0000	1.0000	1.0000	0.8648	1.0476		0.8570	19
Entebbe	Uganda	0.7606	1.0000	1.0000	1.0000	1.0000	0.6759	0.6796	0.7061	0.8915		0.8571	20
Roosevelt Roads nas	Puerto Rico	1.0000	1.0000	1.0000	1.0000	1.0000	0.3569	0.6022	1.0000	1.0000		0.8843	21
Hosea Kutako	Namibia	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.5504	0.6411	0.9469		0.9043	22
Lusaka Intl	Zambia	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.5885	0.6559	0.9141		0.9065	23
Darwin Intl	Australia	1.0000	0.3115	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000		0.9235	24
Augusto Severo	Brazil	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.6331	0.8569	1.0000		0.9433	25

European En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Ramstein AB	Germany	0.2521	0.2674	0.1559	0.1200	0.1043	0.0587	0.0227	0.1060	0.2000		0.1430	1
Spangdahlem AB	Germany	0.2518	0.2675	0.1537	0.1170	0.1013	0.0553	0.0279	0.1130	0.2092		0.1441	2
Incirlik CDI	Turkey	0.2202	0.2242	0.1963	0.1852	0.1797	0.1651	0.1426	0.1226	0.0998		0.1706	3
Sigonella	Italy	0.2834	0.2853	1.0000	0.1800	0.1523	0.1058	0.0323	0.0351	0.1074		0.2424	4
Mildenhall	England	0.3381	1.0000	0.2250	0.1843	0.1670	0.1159	0.1463	0.2446	0.3555		0.3085	5
Fairford RAF	England	0.2600	1.0000	1.0000	0.1029	0.0834	0.0300	0.0675	0.1675	0.2804		0.3324	6
Moron AB	Spain	0.3347	1.0000	1.0000	0.1649	0.1147	0.0418	0.0864	0.1934	0.3143		0.3611	7
Rota NS	Spain	1.0000	1.0000	1.0000	0.1664	0.1145	0.0404	0.0912	0.2000	0.3229		0.4373	8
Lajes	Potugal	1.0000	1.0000	1.0000	0.1420	0.0752	0.0681	0.2131	0.3626	0.5314		0.4880	9

Pacific En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Elmendorf AFB	Alaska	0.3065	1.0000	0.1331	0.2539	0.1699	0.2368	1.0000	1.0000	1.0000		0.5667	1
Kadena AB	Japan	0.2102	0.1426	0.0653	0.1662	1.0000	1.0000	1.0000	1.0000	1.0000		0.6205	2
Iwakuni MCAS	Japan	0.2988	0.2314	0.1544	0.2549	1.0000	1.0000	1.0000	1.0000	1.0000		0.6599	3
Yokota AB	Japan	0.3261	0.2545	0.1728	0.2796	1.0000	1.0000	1.0000	1.0000	1.0000		0.6703	4
Misawa NAF	Japan	0.4069	0.3364	0.2559	0.3611	1.0000	1.0000	1.0000	1.0000	1.0000		0.7067	5
Andersen AFB	Guam	0.3350	0.2479	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000		0.8425	6
Hickam AFB	Hawaii	1.0000	1.0000	0.2734	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000		0.9193	7

While the above table provides a detailed look into the *Q* values relating to overall travel to Baghdad International in Iraq, Figure 15 provides a graphical representation of the *Q* values achieved by the en route from each of the origins modeled. One important thing to note on the table presented above is the data missing from the Incirlik origin. This was left out of this destinations study because of its proximity to the destination. Since Incirlik is roughly 480 nm from the Iraqi destination, including this airfield as an en route inflates the *Q* value achieved. When distance is calculated from the origin to the destination using each current and potential en route, the deviations are all well over 1 since the distance goal is only about 243 nm. These *Q* value inflations created by using Incirlik as an origin, and therefore it was not included in this part of the study.

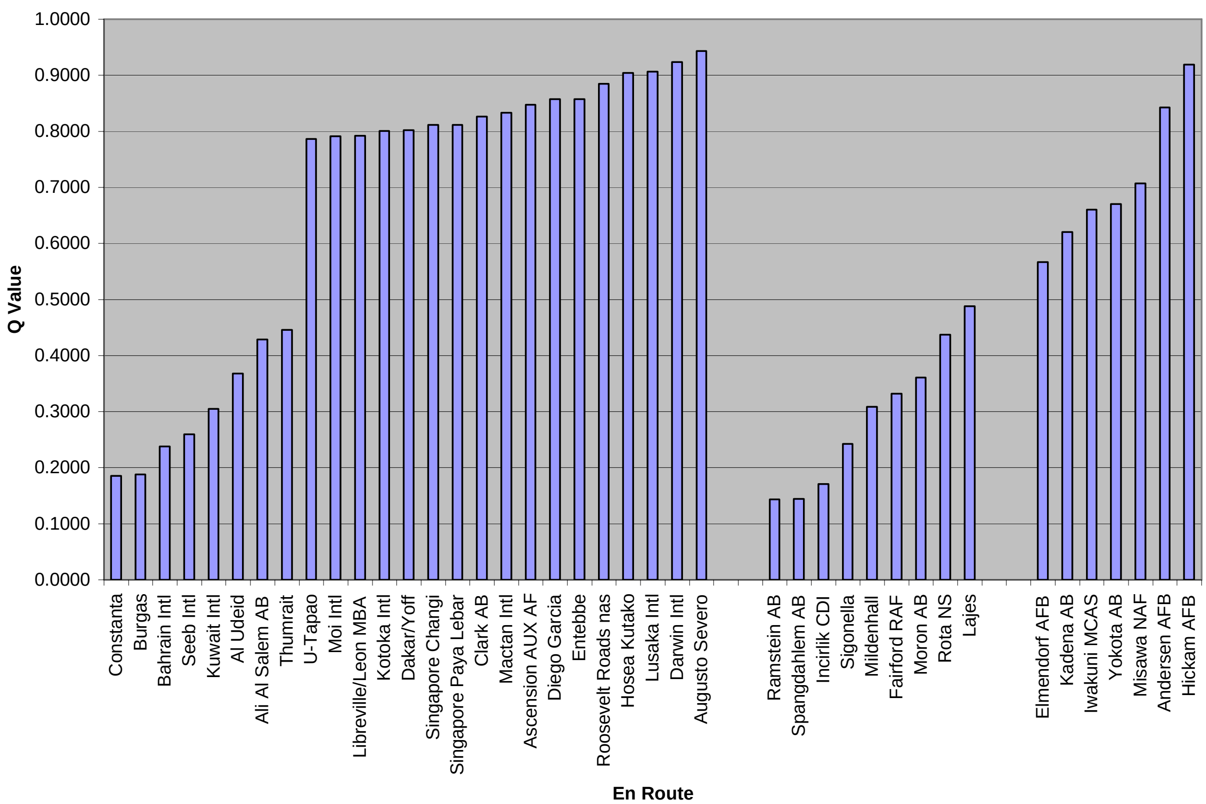


Figure 15. Mean *Q* Values for Destination 5: Southwest Asia

One thing that can be seen while looking at Figure 15, is the poor values achieved by nearly all of the en routes located to the west of the United States. From seeing these values, it is apparent that Southwest Asia is best traveled to using an easterly direction from CONUS.

Additionally, it can be seen that more than two thirds of the potential en route airfields achieve a very poor average *Q* value score when the destination is located in Iraq. This again is representative of the necessary East bound route to Southwest Asia from CONUS. One positive result achieved from studying this destination is that not a single current or potential en route airfield receives an average *Q* value of one. This means that from at least one origin, to the Iraqi destination, every single en route airfield included in the model has at least one route that is less than 8,500 nm distance from origin to en route to destination. This result is primarily achieved due to the central location of Iraq and its overall proximity to all of the en route airfields included in this study.

In summary, of the potential en route airfields included in this model, Constanta, Burgas, and Bahrain International are the best potential en routes to support strategic airlift to this destination.

Destination 6: Central Asia

Figure 6 shows the great circle paths from all potential en route airfields included in the study to Central Asia and the specific destination of Lahor, Pakistan.

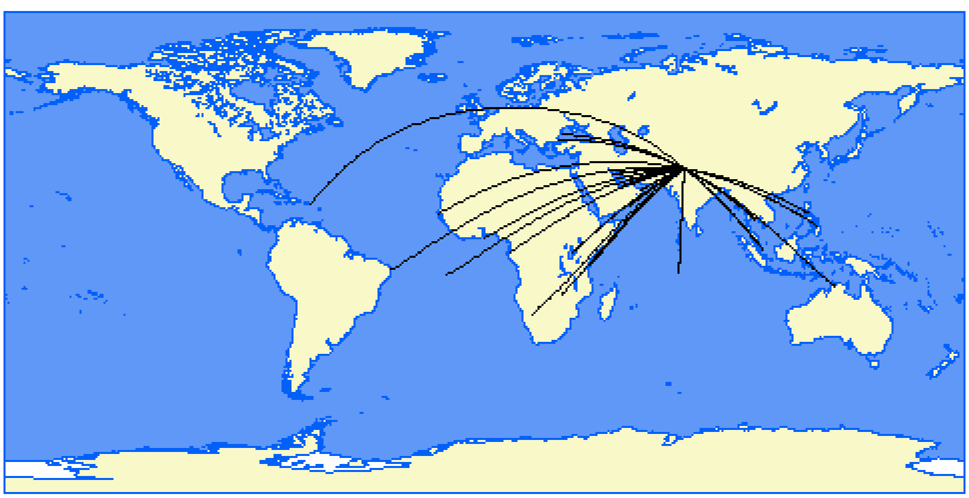


Figure 16. Great Circle Paths to Central Asia Destination (Lahor, Pakistan)

While analyzing each of the en routes' goal program *Q* value score, it is apparent that the average scores to the destination in Central Asia are very similar to the values obtained when studying the Southwest Asia destination. As seen in the goal program scoring technique values shown on Table 8, Seeb International in the country of Oman is the only potential en route airfield that receives a *Q* value lower than any of the en routes currently used. While none of the potential en route airfields scored better in the Southwest Asia destination study, airfields such as Constanta, Burgas, Bahrain International, and Seeb International all provided respectable scores. Consistently low scores achieved while serving as an en route to multiple destinations in this study indicate which airfields could be useful additions to the current en route system.

Table 8. Goal Program Results for Destination 6: Central Asia

Potential En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Seeb Intl	Oman	0.3226	0.2910	0.2588	0.2578	0.2353	0.1993	0.1659	0.1466	0.1616	0.0928	0.2132	1
Bahrain Intl	Bahrain	0.3562	0.3282	1.0000	0.2516	0.2240	0.1750	0.1291	0.1013	0.1101	0.0639	0.2739	2
Constanta	Bulgaria	0.4387	0.4418	1.0000	0.2194	0.1932	0.1273	0.0590	0.0828	0.1412	0.3166	0.3020	3
Burgas	Bulgaria	0.4514	0.4507	1.0000	0.2282	0.1982	0.1293	0.0575	0.0868	0.1461	0.3245	0.3073	4
Kuwait Intl	Kuwait	0.4426	0.4208	1.0000	0.3223	0.2954	0.2438	0.1944	0.1637	0.1645	0.1652	0.3413	5
Thumrait	Oman	0.3717	0.3220	1.0000	0.2907	1.0000	0.2083	0.1669	0.1444	0.1759	0.1122	0.3792	6
Al Udeid	Qatar	0.4820	0.4513	1.0000	0.3817	0.3534	0.3049	0.2599	0.2329	0.2447	0.1871	0.3898	7
Ali Al Salem AB	Kuwait	0.5695	0.5477	1.0000	0.4469	0.4197	0.3674	0.3174	0.2862	0.2867	0.2944	0.4536	8
U-Tapao	Thailand	0.1423	0.0877	0.1868	0.2668	1.0000	1.0000	0.3861	0.4203	0.4658	0.6070	0.4563	9
Singapore Changi	Singapore	0.1964	0.0940	0.2016	0.3188	1.0000	1.0000	1.0000	1.0000	0.5556	0.7292	0.6096	10
Singapore Paya Lebar	Singapore	0.1972	0.0949	0.2024	0.3195	1.0000	1.0000	1.0000	1.0000	0.5556	0.7288	0.6098	11
Clark AB	Philippines	0.2128	0.1455	0.1614	0.2548	1.0000	1.0000	1.0000	1.0000	0.5869	0.8250	0.6186	12
Mactan Intl	Philippines	0.2577	0.1824	0.1600	0.2722	1.0000	1.0000	1.0000	1.0000	1.0000	0.8981	0.6770	13
Moi Intl	Kenya	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.3081	0.2918	0.3918	0.5275	0.7519	14
Diego Garcia	British Terr	0.6046	0.4841	1.0000	1.0000	1.0000	1.0000	0.5512	0.5589	0.6467	0.7262	0.7572	15
Dakar/Yoff	Senegal (Leopold)	1.0000	1.0000	1.0000	1.0000	1.0000	0.3788	0.4822	0.5722	0.7015	1.0905	0.8225	16
Lusaka Intl	Zambia	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.4384	0.4534	0.5757	0.8505	0.8318	17
Entebbe	Uganda	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.5460	0.5226	0.6211	0.8315	0.8521	18
Libreville/Leon MBA	Gabon	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.4382	0.5287	0.6589	1.0504	0.8676	19
Kotoka Intl	Ghana	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.4752	0.5544	0.6683	1.0110	0.8709	20
Darwin Intl	Australia	0.4227	0.3186	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8741	21
Ascension AUX AF	British Terr	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.3334	0.4333	1.0000	1.0000	0.8767	22
Roosevelt Roads nas	Puerto Rico	1.0000	1.0000	1.0000	1.0000	1.0000	0.3757	1.0000	1.0000	1.0000	1.0000	0.9376	23
Hosea Kutako	Namibia	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.4974	1.0000	0.9711	0.9469	24
Augusto Severo	Brazil	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	25

European En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Incirlik CDI	Turkey	0.3914	0.3823	1.0000	0.2055	0.1753	0.1109	0.0457	0.0039	0.0496	0.2000	0.2565	1
Ramstein AB	Germany	0.4363	1.0000	1.0000	0.1369	0.1007	0.0203	0.0641	0.1199	0.2000	0.4410	0.3519	2
Spangdahlem AB	Germany	0.4358	1.0000	1.0000	0.1337	0.0978	0.0174	0.0668	0.1231	0.2041	0.4476	0.3526	3
Fairford RAF	England	1.0000	1.0000	1.0000	0.1189	0.0801	0.0214	0.0923	0.1540	0.2427	0.5095	0.4219	4
Sigonella	Italy	0.4803	1.0000	1.0000	0.2001	1.0000	0.0604	0.0468	0.0989	0.1737	0.3989	0.4459	5
Mildenhall	England	1.0000	1.0000	1.0000	0.2002	0.1637	0.1012	0.1710	0.2318	0.3190	0.5816	0.4769	6
Moron AB	Spain	1.0000	1.0000	1.0000	0.1841	1.0000	0.0473	0.1265	0.1954	0.2945	0.5925	0.5440	7
Rota NS	Spain	1.0000	1.0000	1.0000	1.0000	1.0000	0.0501	0.1303	0.2000	0.3002	0.6016	0.6282	8
Lajes	Potugal	1.0000	1.0000	1.0000	1.0000	1.0000	0.1160	0.2131	0.2975	0.4188	0.7839	0.6829	9

Pcific En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Kadena AB	Japan	0.1816	0.1120	0.0829	0.1474	0.1570	1.0000	1.0000	1.0000	0.5046	0.7717	0.4957	1
Iwakuni MCAS	Japan	0.2825	0.2108	0.1532	0.1945	0.2173	1.0000	1.0000	1.0000	0.5608	0.8459	0.5465	2
Yokota AB	Japan	0.3261	0.2465	0.1352	0.1905	0.2010	1.0000	1.0000	1.0000	0.5775	0.8964	0.5573	3
Misawa NAF	Japan	0.4154	0.3353	0.2157	0.2790	0.2724	1.0000	1.0000	1.0000	0.6368	0.9612	0.6116	4
Elmendorf AFB	Alaska	0.4589	1.0000	0.1544	0.2539	0.1505	0.1636	1.0000	1.0000	1.0000	1.0000	0.6181	5
Andersen AFB	Guam	0.3472	0.2479	0.0959	0.1780	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.6869	6
Hickam AFB	Hawaii	1.0000	1.0000	0.2734	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9273	7

In Figure 17, it can be seen that only one of the potential en route airfields received an average *Q* value of one. This is different from several of the other destination studies in which many potential en route airfields received an average *Q* value of one. Since only one airfield received an average *Q* value of one, this destination, just like the Southwest Asia destination, is located in an area that is more easily reached from en route locations. This indicates that Central Asia and Southwest Asia are destinations that require less en route additions to reach them effectively. Although less importance may be attributed to these particular areas, the goal program scoring technique *Q* values retrieved here can still be used to help determine which en routes would be the most robust additions to the current infrastructure. By describing these airfields as robust, they can effectively be used as en route waypoints to multiple destinations to help fight the GWOT.

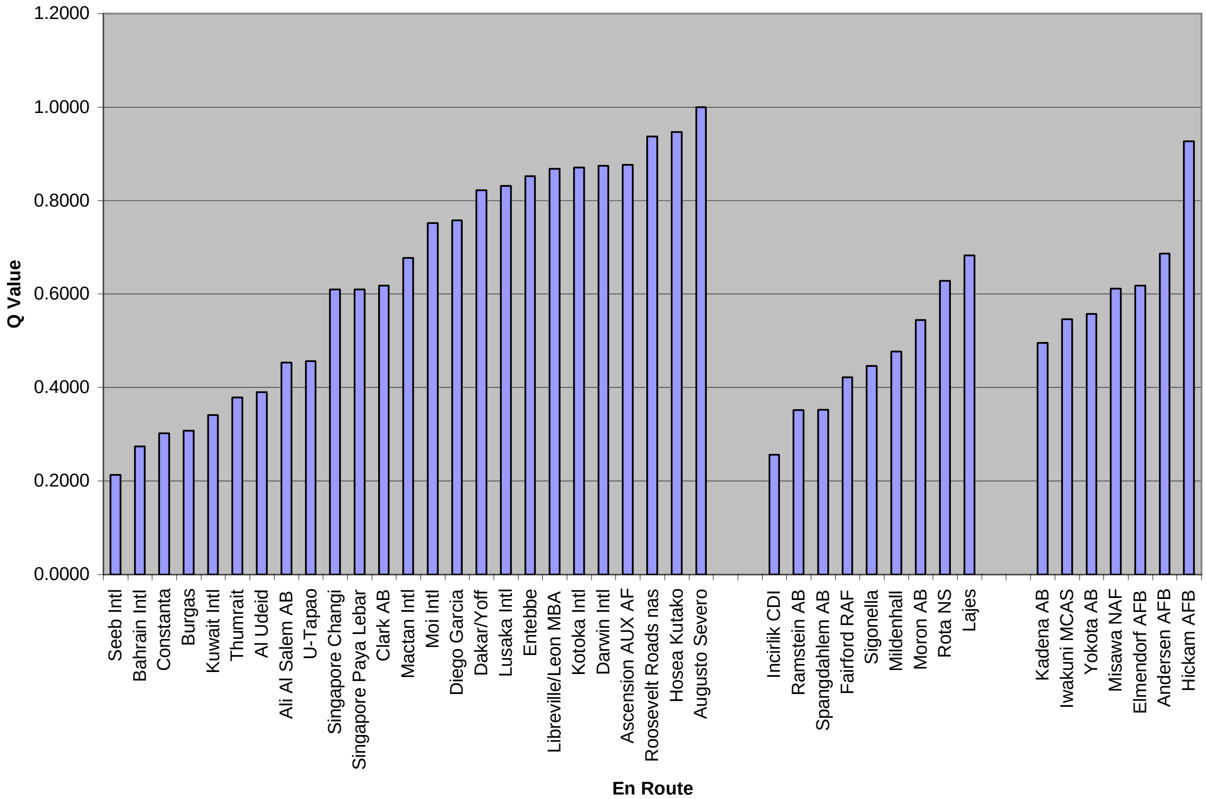


Figure 17. Mean *Q* Values for Destination 6: Central Asia

In summary, of the potential en route airfields included in this model, Seeb International, Bahrain International, and Constanta are the best potential en routes to support strategic airlift to this destination.

Destination 7: Western Africa

A graphical representation of the routes from each potential en route airfield included in the model to the Western Africa destination is shown in Figure 18.

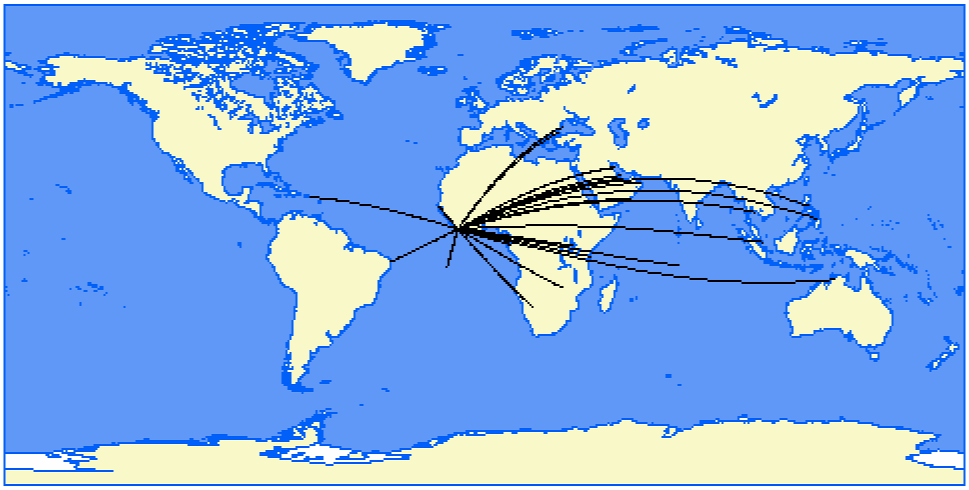


Figure 18. Great Circle Paths to Western Africa Destination (Monrovia, Liberia)

To study the destination of Western Africa, Monrovia airfield located in Liberia was used in the model. This portion of the study, where destinations located in Africa are analyzed, clearly shows the necessity for additional en route airfields to effectively reach the African continent. As can be seen in Table 9, consistently low *Q* scores are difficult to achieve when flying to this area. The reason for this difficulty is mainly due to its distance from CONUS and other countries that might host potential en routes. The continent of Africa is separated from CONUS by the Atlantic Ocean. Additionally, the European bases used and maintained by the United States are located too far north to reach Western Africa within a reasonable distance. This fact clearly shows that destinations in the African continent require the addition of another en route airfield to be reached effectively by strategic airlift. With the current global war on terrorism continually presenting the potential for new hotspots all of the time, robust en route airfields need to be devised so they can be of use if and when the need arises.

Table 9. Goal Program Results for Destination 7: Western Africa

Potential En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Dakar/Yoff	Senegal (Leopold)	0.4426	1.0000	0.4243	0.4166	0.4136	0.3913	0.3397	0.3699	0.4079	0.4561	0.4662	1
Burgas	Bulgaria	0.0977	1.0000	1.0000	0.1386	1.0000	0.2845	0.3999	0.4941	0.2811	0.2314	0.4927	2
Constanta	Bulgaria	0.0924	1.0000	1.0000	0.1319	1.0000	0.2814	0.4181	0.5154	0.2954	0.2441	0.4979	3
Roosevelt Roads nas	Puerto Rico	1.0000	1.0000	0.1730	0.1951	0.1397	0.2549	0.5393	0.6445	0.4965	1.0000	0.5443	4
Ascension AUX AF	British Terr	1.0000	1.0000	1.0000	0.3054	0.2836	0.3000	0.3975	0.4510	0.3893	0.3607	0.5488	5
Libreville/Leon MBA	Gabon	0.4223	1.0000	1.0000	0.4309	0.4266	0.4358	0.4725	0.4827	0.4555	0.4354	0.5562	6
Kotoka Intl	Ghana	0.4830	1.0000	1.0000	0.5132	0.5302	0.5489	0.5583	0.5116	0.4869	0.4488	0.6081	7
Augusto Severo	Brazil	1.0000	1.0000	1.0000	0.4394	0.3893	0.3839	0.5394	0.6924	0.6170	0.6405	0.6702	8
Bahrain Intl	Bahrain	0.0291	1.0000	1.0000	1.0000	1.0000	1.0000	0.5221	0.5998	0.3354	0.2737	0.6760	9
Thumrait	Oman	0.0354	1.0000	1.0000	1.0000	1.0000	1.0000	0.6051	0.6316	0.3567	0.2925	0.6921	10
Seeb Intl	Oman	0.0152	1.0000	1.0000	1.0000	1.0000	1.0000	0.6027	0.6866	0.3935	0.3251	0.7023	11
Kuwait Intl	Kuwait	0.1137	1.0000	1.0000	1.0000	1.0000	1.0000	0.5658	0.6589	0.4025	0.3427	0.7083	12
Al Udeid	Qatar	0.1544	1.0000	1.0000	1.0000	1.0000	1.0000	0.6597	0.7309	0.4645	0.4023	0.7412	13
Ali Al Salem AB	Kuwait	0.2394	1.0000	1.0000	1.0000	1.0000	1.0000	0.6864	0.7794	0.5245	0.4650	0.7695	14
Moi Intl	Kenya	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.7612	0.6991	0.4548	0.3222	0.8237	15
Lusaka Intl	Zambia	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8928	0.8601	0.6461	0.4654	0.8864	16
Hosea Kutako	Namibia	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8513	0.8511	0.6585	0.5036	0.8865	17
Entebbe	Uganda	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9504	0.8763	0.6773	0.5408	0.9045	18
Diego Garcia	British Terr	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.6799	0.9680	19
Darwin Intl	Australia	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	20
Clark AB	Philippines	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	20
Mactan Intl	Philippines	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	20
Singapore Changi	Singapore	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	20
Singapore Paya Lebar	Singapore	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	20
U-Tapao	Thailand	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	20

European En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Lajes	Potugal	0.1362	1.0000	0.1156	0.0773	0.0870	0.0353	0.2131	0.2815	0.1267	0.1870	0.2260	1
Rota NS	Spain	0.1122	1.0000	1.0000	0.0943	0.1287	0.1185	0.1415	0.2000	0.0678	0.0563	0.2919	2
Moron AB	Spain	0.1099	1.0000	1.0000	0.0931	0.1289	0.1203	0.1482	0.2079	0.0730	0.0509	0.2932	3
Sigonella	Italy	0.0802	1.0000	1.0000	0.1053	0.1682	0.2051	0.2317	0.3056	0.1384	0.0994	0.3334	4
Fairford RAF	England	0.0666	1.0000	1.0000	0.0433	0.0961	0.1047	0.3127	0.4005	0.2020	0.1556	0.3382	5
Spangdahlem AB	Germany	0.0618	1.0000	1.0000	0.0546	0.1149	0.1383	0.3128	0.4006	0.2021	0.1557	0.3441	6
Ramstein AB	Germany	0.0620	1.0000	1.0000	0.0570	0.1180	0.1428	0.3102	0.3975	0.2000	0.1539	0.3441	7
Mildenhall	England	0.1469	1.0000	1.0000	0.1251	0.1798	0.1915	0.4053	0.4946	0.2925	0.2454	0.4081	8
Incirlik CDI	Turkey	0.0435	1.0000	1.0000	0.1094	1.0000	0.2838	0.3767	0.4754	0.2521	0.2000	0.4741	9

Pacific En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Elmendorf AFB	Alaska	1.0000	1.0000	1.0000	0.2539	0.2650	1.0000	1.0000	1.0000	1.0000	1.0000	0.8519	1
Kadena AB	Japan	0.2278	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9228	2
Hickam AFB	Hawaii	1.0000	1.0000	0.2734	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9273	3
Iwakuni MCAS	Japan	0.3128	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9313	4
Yokota AB	Japan	0.3261	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9326	5
Misawa NAF	Japan	0.4039	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9404	6
Andersen AFB	Guam	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	7

The bar chart for the Western Africa destination is presented in Figure 19. As can be seen in this figure, en routes used to reach the Western Africa destination do not produce very good (i.e., low) *Q* values. The current en routes located in Europe are the only airfields included in the model which do yield low *Q* values in the goal program. An important finding is that the best en routes in the European en route system appear to be Lajes, NAS Rota, and Moron AB. These airfields receive good values because of their locations and high fuel, MOG capabilities. Lajes is located on an island in the Atlantic Ocean midway between CONUS and Europe, and to the Northeast of Africa. Since this is one of the few en route airfields that is located somewhat between CONUS and the African continent, it receives the best *Q* value. The remaining factors considered of the en route airfield at Lajes help it achieve a low *Q* score as well. NAS Rota and Moron AB are also somewhat close to achieving a more direct route from CONUS to Africa. For the potential en route airfields, Roosevelt Roads is also somewhat located in between CONUS and Africa, providing a fair critical leg distance. This airfield does not, however, receive an overall good *Q* value because it has a fairly poor fuel capacity value. It has a fuel capacity of one which penalizes it somewhat in its *Q* value calculation. Dakar, Burgas and Constanta actually receive better *Q* values than the other potential en route airfields because they have better critical leg distances from several of the other European en routes used as origins in the model.

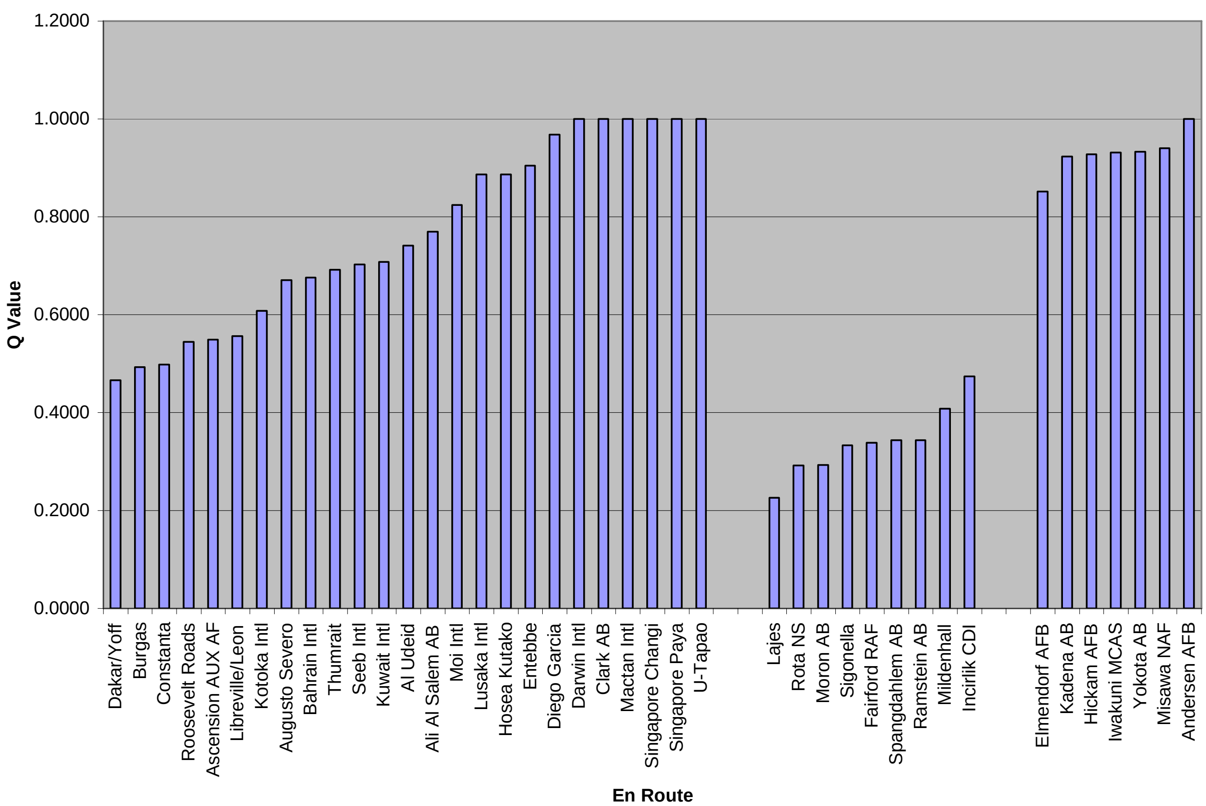


Figure 19. Mean *Q* Values for Destination 7: Western Africa

In summary, of the potential en route airfields included in this model, Dakar, Burgas, and Constanta are the best potential en routes to support strategic airlift to this destination

Destination 8: Southern Africa

Figure 20 shows the great circle paths from all potential en route airfields included in the study to Southern Africa and the specific destination of Waterkloof, South Africa.

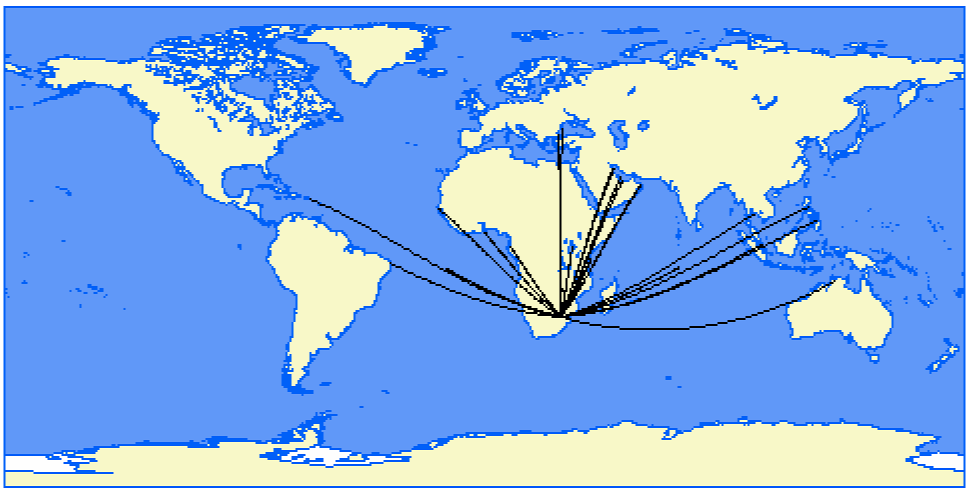


Figure 20. Great Circle Paths to Southern Africa Destination (Waterkloof, South Africa)

The resultant *Q* values calculated here provided for useful analysis and can be seen in Table 10. The most apparent result for the goal program used to model en routes to this destination, is the poor values that nearly every en route achieved. Certainly, the overall poor values achieved here are due to the somewhat distant location of this destination. Obtaining an en route AB midway between CONUS and South Africa is difficult due to the extreme southern location of South Africa. If en route bases were to be located somewhere in the northern portion of the African continent, the extreme distance to South Africa would not exist. In this particular study, it would seem that several of the potential en route airfields that are located on the African continent and included in the goal program, would achieve the best Q values to this destination. Unfortunately, these airfields do not achieve scores that are in the top three to this destination. The reason for this is not directly due to its critical leg distance, but due to the poor values they have for the other factors included in the model.

From many modeled origins, the potential en route airfields located on the African continent had the lowest deviation to the critical leg distance goal. It was the other factors included in the model that caused these airfields to achieve such poor scores. Of the seven African airfields included in the model, only two, Lusaka International and Hosea Kutako, had a MOG value, m, that even equaled the target of six. In fact, none of the potential en routes had a value that exceeded the target. Additionally, only one of these airfields had a fuel capacity value of three, and none of them had an airfields in range value, a, that even came close to the goal of 500. If some of these airfields in Africa are determined to be helpful en route airfield locations, it is obvious that work and capital will need to be applied to these bases to improve their current capabilities.

Table 10. Goal Program Results for Destination 8: Southern Africa

Potential En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Thumrait	Oman	0.0512	0.0899	1.0000	1.0000	1.0000	1.0000	0.1494	0.1179	0.0593	0.1178	0.4585	1
Seeb Intl	Oman	0.0296	0.0727	1.0000	1.0000	1.0000	1.0000	0.1483	0.1255	0.0960	0.1629	0.4635	2
Moi Intl	Kenya	0.2596	0.2823	1.0000	1.0000	1.0000	0.3141	0.2900	0.2639	0.2396	0.1896	0.4839	3
Bahrain Intl	Bahrain	0.0444	1.0000	1.0000	1.0000	1.0000	1.0000	0.1133	0.1202	0.0912	0.1570	0.5526	4
Ascension AUX AF	British Terr	1.0000	1.0000	1.0000	1.0000	1.0000	0.1136	0.0935	0.1174	0.1730	0.2701	0.5768	5
Hosea Kutako	Namibia	0.4491	0.4584	1.0000	1.0000	1.0000	0.3913	0.3840	0.3848	0.3997	0.4171	0.5884	6
Lusaka Intl	Zambia	0.4397	0.4544	1.0000	1.0000	1.0000	0.4377	0.4201	0.4068	0.4055	0.3916	0.5956	7
Kuwait Intl	Kuwait	0.1291	1.0000	1.0000	1.0000	1.0000	1.0000	0.1795	0.2139	0.1839	0.2518	0.5958	8
Burgas	Bulgaria	1.0000	1.0000	1.0000	1.0000	1.0000	0.1002	0.1807	0.2383	0.2032	0.2829	0.6005	9
Al Udeid	Qatar	0.1697	1.0000	1.0000	1.0000	1.0000	1.0000	0.2438	0.2408	0.2122	0.2770	0.6144	10
Libreville/Leon MBA	Gabon	1.0000	1.0000	1.0000	1.0000	1.0000	0.2548	0.2259	0.2636	0.2729	0.3583	0.6375	11
Ali Al Salem AB	Kuwait	0.2549	1.0000	1.0000	1.0000	1.0000	1.0000	0.3026	0.3388	0.3089	0.3768	0.6582	12
Entebbe	Uganda	0.5494	0.5810	1.0000	1.0000	1.0000	0.5649	0.5298	0.4984	0.4851	0.4420	0.6651	13
Kotoka Intl	Ghana	1.0000	1.0000	1.0000	1.0000	1.0000	0.3584	0.3018	0.3370	0.3286	0.3856	0.6711	14
Dakar/Yoff	Senegal (Leopold)	1.0000	1.0000	1.0000	1.0000	1.0000	0.2635	0.3472	0.3979	0.3669	0.4371	0.6813	15
Diego Garcia	British Terr	0.2843	0.2837	1.0000	1.0000	1.0000	1.0000	1.0000	0.5185	0.4451	0.3891	0.6921	16
Constanta	Bulgaria	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1893	0.2485	0.2123	0.2942	0.6944	17
Augusto Severo	Brazil	1.0000	1.0000	1.0000	1.0000	1.0000	0.2538	0.3421	0.3957	0.3788	1.0000	0.7370	18
Singapore Changi	Singapore	0.0963	0.0995	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8196	19
U-Tapao	Thailand	0.0964	0.0997	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8196	20
Singapore Paya Lebar	Singapore	0.0965	0.0997	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8196	21
Clark AB	Philippines	0.2000	0.2041	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8404	22
Mactan Intl	Philippines	0.2079	0.2120	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8420	23
Roosevelt Roads nas	Puerto Rico	1.0000	1.0000	1.0000	1.0000	1.0000	0.2736	0.4141	1.0000	1.0000	1.0000	0.8688	24
Darwin Intl	Australia	1.0000	0.2191	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9219	25

European En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Sigonella	Italy	1.0000	1.0000	1.0000	1.0000	1.0000	0.0333	0.1116	0.1659	0.1328	0.2080	0.5652	1
Rota NS	Spain	1.0000	1.0000	1.0000	1.0000	1.0000	0.0427	0.1406	0.2000	0.1638	0.2459	0.5793	2
Moron AB	Spain	1.0000	1.0000	1.0000	1.0000	1.0000	0.0432	0.1412	0.2007	0.1644	0.2467	0.5796	3
Ramstein AB	Germany	1.0000	1.0000	1.0000	1.0000	1.0000	0.0669	0.1746	0.2399	0.2000	0.2904	0.5972	4
Spangdahlem AB	Germany	1.0000	1.0000	1.0000	1.0000	1.0000	0.0693	0.1780	0.2438	0.2036	0.2948	0.5990	5
Fairford RAF	England	1.0000	1.0000	1.0000	1.0000	1.0000	0.0821	0.1958	0.2648	0.2227	0.3182	0.6084	6
Lajes	Potugal	1.0000	1.0000	1.0000	1.0000	1.0000	0.0981	0.2131	0.2827	0.2402	0.3367	0.6171	7
Mildenhall	England	1.0000	1.0000	1.0000	1.0000	1.0000	0.1662	0.2803	0.3495	0.3073	0.4030	0.6506	8
Incirlik CDI	Turkey	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1056	0.1588	0.1263	0.2000	0.6591	9

Pacific En Routes	Country	Yokota AB	Andersen AFB	Hickam	Elmendorf AFB	Travis AFB	Dover AFB	Lajes AB	Rota NS	Ramstein AB	Incirlik	Mean Value	Order
Kadena AB	Japan	0.1920	0.1965	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8389	1
Iwakuni MCAS	Japan	0.3019	0.3067	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8609	2
Andersen AFB	Guam	1.0000	0.2479	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9248	3
Yokota AB	Japan	0.3261	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9326	4
Misawa NAF	Japan	0.4206	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9421	5
Hickam AFB	Hawaii	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	6
Elmendorf AFB	Alaska	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	6

The difficulty in reaching a destination located in Southern Africa is even more apparent in Figure 21. In this graphical representation of the en route *Q* values calculated by the goal program, none of the en route airfields currently being used produce an average *Q* value less than 0.5. After seeing the average values obtained by all of the en route airfields to all of the other modeled destinations, it is obvious that Southern South Africa is one of the most difficult locations for the United States to provide rapid air mobility. Due to its distant destination, and the lack of potential en route airfields located near it, Southern Africa is an area where further analysis needs to be done so that travel to this vicinity will become less difficult. The fact that five of the potential en route airfields analyzed in this model obtained lower *Q* scores than any of the existing ones shows the necessity for additional airfields such as Thumrait, Seeb International, or Moi International to reach these African destinations efficiently.

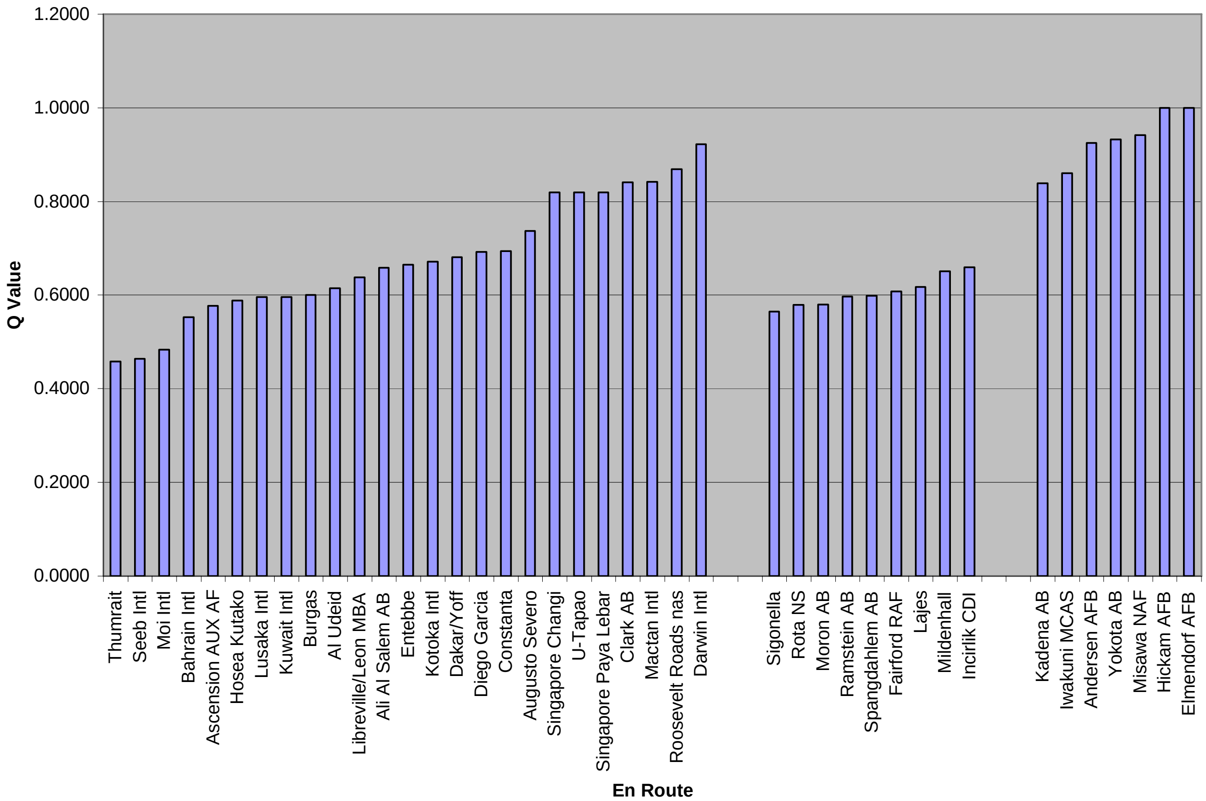


Figure 21. Mean *Q* Values for Destination 8: Southern Africa

Additional information that is gained from Figure 21 is the comparison of the *Q* values calculated for the potential en route airfields versus those obtained for the current en routes. Four of the potential en route *Q* scores are the lowest values obtained in the GERST. In addition, nearly half of the twenty five values calculated for the potential en route airfields are lower than every single one obtained by any of the current en route airfields. As was mentioned previously, a destination in this region of the world is certainly in need of additional en route airfields to support strategic airlift transportation to this area. By calculating the *Q* values for twenty five potential additions to the current en route system, results obtained show the necessity for the addition of at least one of the potential en route airfields studied to help strategic airlift assets reach these destinations effectively.

In summary, of the potential en route airfields included in this model, Thumrait, Seeb International, and Moi International are the best potential en routes to support strategic airlift to the destination in Southern Africa.

While analyzing the destinations strictly to the east of CONUS the best three potential en route Q values achieved to each particular destination are presented below.

Destination 5: Southwest Asia: (Baghdad International, Iraq)

1) Constanta, Bulgaria, $Q = 0.1851$

2) Burgas, Bulgaria, $Q = 0.1876$

3) Bahrain Int'l, Bahrain, $Q = 0.2376$

Destination 6: Central Asia: (Lahore, Pakistan)

1) Seeb International, Oman, $Q = 0.2132$

2) Bahrain International, Bahrain, $Q = 0.2739$

3) Constanta, Bulgaria, $Q = 0.3020$

Destination 7: Western Africa: (Monrovia, Liberia)

1) Dakar, Senegal, $Q = 0.4662$

2) Burgas, Bulgaria, $Q = 0.4927$

3) Constanta, Bulgaria, $Q = 0.4979$

Destination 8: Southern South Africa: (Waterkloof, South Africa)

1) Thumrait, Oman, $Q = 0.4585$

2) Seeb International, Oman, $Q = 0.4635$

3) Moi International, Kenya, $Q = 0.4939$

Global En Route Analysis

In the previous paragraphs, each of the eight destinations included in the model were assigned to one of two sets chosen based on their location relative to the United States, and then studied individually. One section studied the usefulness of the potential en routes based on their ability to support to airlift destinations East of CONUS while another studied en route performance to destinations to the West of CONUS. While each of these analyses may be helpful to the PERISC and EERISC respectively based on the location of the destinations, these studies need to be combined to provide a more global examination in support of the GWOT.

Previously, all of the potential and current en routes were studied based on the Q values they achieved in routes from all of the ten origins to each particular destination. In fact, the Q value obtained by the en routes to each modeled destination was an average based on the value obtained from each of the ten origins. For a more global perspective, each of the mean Q values averaged over all ten origins before will be averaged again over all eight of the destinations. The overall average Q value for each en route airfield is now averaged from all ten origins to each of the eight destinations. That is, operating under uncertainty, a better representation of the effectiveness of an en route airfield to support the GWOT. Table 11 presents the overall average Q value for each of the modeled en route airfields with respect to all origins and destinations included in the goal programming model. Additionally, Table 12 shows the average rank that each potential en route achieved among the other prospective airfields modeled. In addition to these tables, Figure 22 and Figure 23 give a graphical representation of the overall average Q values obtained and the overall average ranking of the potential en route airfields.

Table 11. Overall Average *Q* Value for all Origins and destinations

Potential En Routes	Country	Bahia Blanca	Gao Airfield	Seoul AB	Dili (East Timor)	Baghdad Int'l	Monrovia	Waterkloof	Lahore	Avg Q Value	Avg Rank
Seeb Intl	Oman	1.0000	0.1632	0.5920	0.7190	0.2594	0.7023	0.4635	0.2132	0.5141	6
Burgas	Bulgaria	0.7872	0.4294	0.6411	0.7650	0.1876	0.4927	0.6005	0.3073	0.5264	7
Bahrain Intl	Bahrain	0.9220	0.2330	0.6031	0.7270	0.2376	0.6760	0.5526	0.2739	0.5282	6
Constanta	Bulgaria	0.8530	0.3423	0.6377	0.7642	0.1851	0.4979	0.6944	0.3020	0.5346	7
Kuwait Intl	Kuwait	0.9302	0.3033	0.6410	0.7553	0.3050	0.7083	0.5958	0.3413	0.5725	8
Thumrait	Oman	1.0000	0.3367	0.6097	0.7214	0.4456	0.6921	0.4585	0.3792	0.5804	8
Al Udeid	Qatar	0.9345	0.3476	0.6593	0.7636	0.3682	0.7412	0.6144	0.3898	0.6023	10
Ali Al Salem AB	Kuwait	0.9426	0.4157	0.6971	0.7932	0.4288	0.7695	0.6582	0.4536	0.6448	12
U-Tapao	Thailand	1.0000	0.3225	0.5552	0.4451	0.7868	1.0000	0.8196	0.4563	0.6732	11
Clark AB	Philippines	1.0000	0.5738	0.4111	0.3602	0.8260	1.0000	0.8404	0.6186	0.7038	13
Mactan Intl	Philippines	1.0000	0.6409	0.5041	0.3680	0.8328	1.0000	0.8420	0.6770	0.7331	13
Singapore Changi	Singapore	1.0000	0.5050	0.6642	0.4709	0.8115	1.0000	0.8196	0.6096	0.7351	13
Singapore Paya Lebar	Singapore	1.0000	0.5053	0.6646	0.4714	0.8116	1.0000	0.8196	0.6098	0.7353	14
Ascension AUX AF	British Terr	0.5604	0.8623	1.0000	1.0000	0.8472	0.5488	0.5768	0.8767	0.7840	14
Dakar/Yoff	Senegal (Leopold)	0.6729	0.8519	1.0000	1.0000	0.8017	0.4662	0.6813	0.8225	0.7871	14
Libreville/Leon MBA	Gabon	0.6420	0.8226	1.0000	1.0000	0.7922	0.5562	0.6375	0.8676	0.7898	13
Moi Intl	Kenya	0.9258	0.6749	0.9387	0.9287	0.7910	0.8237	0.4839	0.7519	0.7898	13
Kotoka Intl	Ghana	0.7577	0.8319	1.0000	1.0000	0.8003	0.6081	0.6711	0.8709	0.8175	15
Diego Garcia	British Terr	1.0000	0.6649	0.9358	0.7629	0.8570	0.9680	0.6921	0.7572	0.8297	16
Roosevelt Roads nas	Puerto Rico	0.5080	1.0000	1.0000	1.0000	0.8843	0.5443	0.8688	0.9376	0.8429	17
Darwin Intl	Australia	1.0000	0.7740	0.8855	0.4472	0.9235	1.0000	0.9219	0.8741	0.8533	18
Hosea Kutako	Namibia	0.7880	0.7928	1.0000	1.0000	0.9043	0.8865	0.5884	0.9469	0.8633	16
Augusto Severo	Brazil	0.5842	1.0000	1.0000	1.0000	0.9433	0.6702	0.7370	1.0000	0.8668	17
Lusaka Intl	Zambia	0.9334	0.7873	1.0000	1.0000	0.9065	0.8864	0.5956	0.8318	0.8676	16
Entebbe	Uganda	0.9527	0.8186	0.9717	0.9598	0.8571	0.9045	0.6651	0.8521	0.8727	17

European En Routes	Country	Bahia Blanca	Gao Airfield	Seoul AB	Dili (East Timor)	Baghdad Int'l	Monrovia	Waterkloof	Lahore		
Ramstein AB	Germany	0.6950	0.4950	0.5334	0.6763	0.1430	0.3441	0.5972	0.3519	0.4795	3
Spangdahlem AB	Germany	0.6948	0.4967	0.5335	0.6768	0.1441	0.3441	0.5990	0.3526	0.4802	4
Incirlik CDI	Turkey	0.8437	0.3186	0.6146	0.7430	0.1706	0.4741	0.6591	0.2565	0.5100	5
Sigonella	Italy	0.6893	0.4840	0.6417	0.7606	0.2424	0.3334	0.5652	0.4459	0.5203	4
Fairford RAF	England	0.6903	0.5137	0.5393	0.7527	0.3324	0.3382	0.6084	0.4219	0.5246	5
Mildenhall	England	0.7253	0.5610	0.5830	0.7767	0.3085	0.4081	0.6506	0.4769	0.5613	6
Moron AB	Spain	0.6699	0.6148	0.6652	0.9198	0.3611	0.2932	0.5796	0.5440	0.5810	6
Rota NS	Spain	0.6686	0.6168	0.6668	0.9200	0.4373	0.2919	0.5793	0.6282	0.6011	6
Lajes	Potugal	0.5857	0.6693	0.6654	0.9213	0.4880	0.2260	0.6171	0.6829	0.6070	7

Pacific En Routes	Country	Bahia Blanca	Gao Airfield	Seoul AB	Dili (East Timor)	Baghdad Int'l	Monrovia	Waterkloof	Lahore		
Kadena AB	Japan	1.0000	0.4547	0.2547	0.3298	0.6205	0.9228	0.8389	0.4957	0.6146	3
Iwakuni MCAS	Japan	1.0000	0.5111	0.3225	0.4843	0.6599	0.9313	0.8609	0.5465	0.6646	4
Yokota AB	Japan	1.0000	0.5802	0.3168	0.4892	0.6703	0.9326	0.9326	0.5573	0.6849	4
Elmendorf AFB	Alaska	0.9254	0.7597	0.2505	0.7768	0.5667	0.8519	0.9254	0.6181	0.7093	3
Misawa NAF	Japan	1.0000	0.6326	0.3940	0.5578	0.7067	0.9404	0.9421	0.6116	0.7231	4
Andersen AFB	Guam	1.0000	0.6757	0.5359	0.4217	0.8425	1.0000	0.9248	0.6869	0.7609	6
Hickam AFB	Hawaii	0.9273	0.9273	0.6410	0.7195	0.9193	0.9273	1.0000	0.9273	0.8736	5

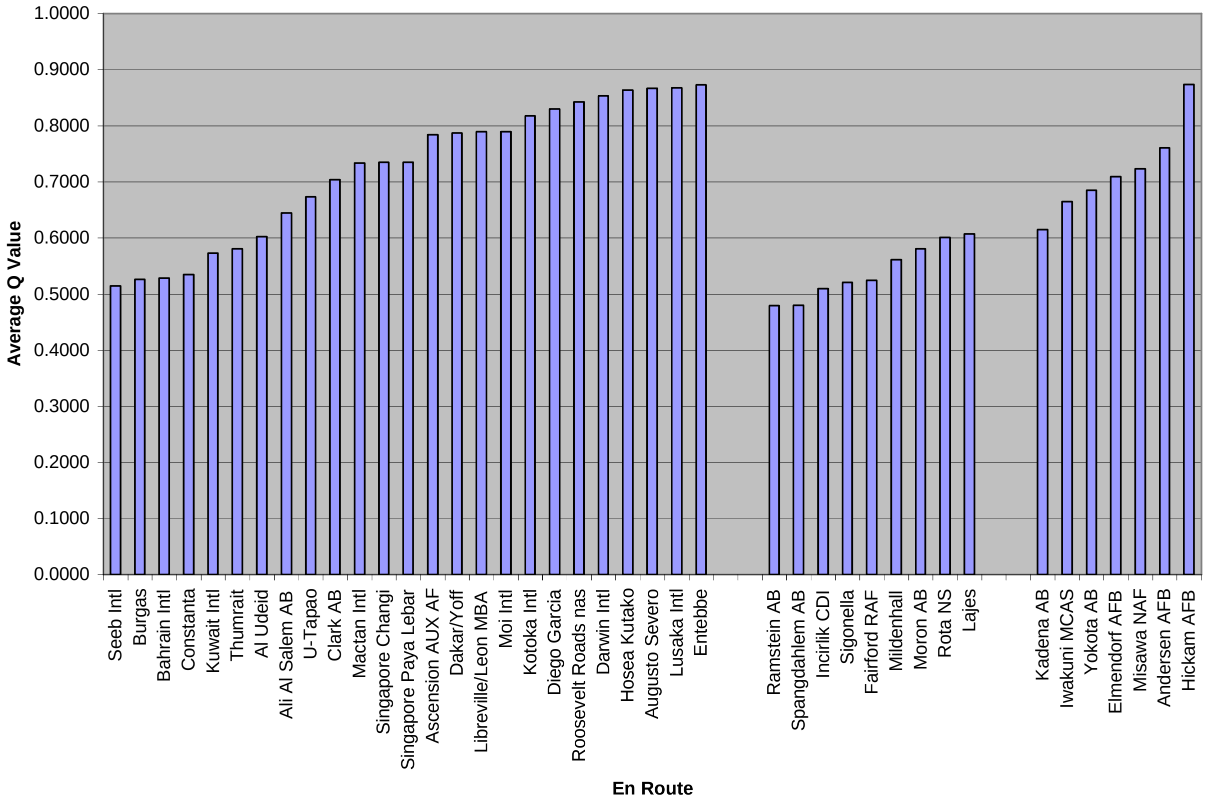


Figure 22. Overall Average *Q* Value for all Origins and Destinations

The information presented in Figure 22 above provides a good deal of useful insight. First, three of the European en route airfields have average *Q* values that are the lowest received in the model by any airfield. The surprising aspect of this result is that only three current en route airfields obtain a *Q* value better than every potential en route airfields. Few current en routes have extremely superior *Q* values because of the targets that were defined in the goal program and the destinations chosen. The main reason for this is that the current en routes were designed to support strategic airlift to Southwest Asia and Northeast Asia, not the other potential GWOT destinations studied. Moreover, they have been modernized with more infrastructure (MOG and fuel) so they are expected to perform well. If the potential en routes were modernized, they would likely perform equally well or better than the current en routes when traveling to destinations other than NEA and SWA. This is why we are studying these new potential en routes. Alternative en route strategies need to be devised to transit to new global destinations to support the GWOT.

Further information that can be gathered from Table 11 and Figure 22 is the poor Q values achieved by all of the current Pacific en route airfields. The sparseness of land in this region of the globe is the main reason for such poor values obtained here. The goal programming based scoring technique includes the critical leg distance from origins to en routes and en routes to destinations. The en routes designed to support strategic airlift to Northeast Asia are located in areas that provide efficient critical leg distances when traveling to this region. Due to the position of these locations, the critical leg distances to alternate potential GWOT destinations is not as efficient. Since we are studying potential en route airfields and their ability to support global strategic mobility, it would seem that airfields located to the west of CONUS are probably not good additions to help fight the GWOT. However, if specific destinations in the Pacific are defined most probable in the GWOT, then some of these may still be good choices.

Table 12. Overall Average Ranking Within Each Set

Potential En Routes	Country	Bahia Blanca	Gao Airfield	Seoul AB	Dili (East Timor)	Baghdad Int'l	Monrovia	Waterkloof	Lahore	Average Rank
Bahrain Intl	Bahrain	10	2	5	9	3	9	4	2	5.50
Seeb Intl	Oman	17	1	4	7	4	11	2	1	5.88
Burgas	Bulgaria	7	9	9	14	2	2	9	4	7.00
Constanta	Bulgaria	9	6	7	13	1	3	17	3	7.38
Thumrait	Oman	17	5	6	8	8	10	1	6	7.63
Kuwait Intl	Kuwait	12	3	8	10	5	12	8	5	7.88
Al Udeid	Qatar	14	7	10	12	6	13	10	7	9.88
U-Tapao	Thailand	17	4	3	3	9	20	20	9	10.63
Ali Al Salem AB	Kuwait	15	8	13	15	7	14	12	8	11.50
Moi Intl	Kenya	11	15	16	16	10	15	3	14	12.50
Clark AB	Philippines	17	12	1	1	16	20	22	12	12.63
Singapore Changi	Singapore	17	10	11	5	14	20	19	10	13.25
Libreville/Leon MBA	Gabon	4	20	18	18	11	6	11	19	13.38
Mactan Intl	Philippines	17	13	2	2	17	20	23	13	13.38
Dakar/Yoff	Senegal (Leopold)	5	22	18	18	13	1	15	16	13.50
Ascension AUX AF	British Terr	2	23	18	18	18	5	5	22	13.88
Singapore Paya Lebar	Singapore	17	11	12	6	15	20	21	11	14.13
Kotoka Intl	Ghana	6	21	18	18	12	7	14	20	14.50
Diego Garcia	British Terr	17	14	15	11	19	19	16	15	15.75
Lusaka Intl	Zambia	13	17	18	18	23	16	7	17	16.13
Hosea Kutako	Namibia	8	18	18	18	22	17	6	24	16.38
Roosevelt Roads nas	Puerto Rico	1	24	18	18	21	4	24	23	16.63
Entebbe	Uganda	16	19	17	17	20	18	13	18	17.25
Augusto Severo	Brazil	3	24	18	18	25	8	18	25	17.38
Darwin Intl	Australia	17	16	14	4	24	20	25	21	17.63

	Country	Bahia Blanca	Gao Airfield	Seoul AB	Dili (East Timor)	Baghdad Int'l	Monrovia	Waterkloof	Lahore	Average Rank
Ramstein AB	Germany	7	3	1	1	1	7	4	2	3.25
Spangdahlem AB	Germany	6	4	2	2	2	6	5	3	3.75
Sigonella	Italy	4	2	6	5	4	4	1	5	3.88
Fairford RAF	England	5	5	3	4	6	5	6	4	4.75
Incirlik CDI	Turkey	9	1	5	3	3	9	9	1	5.00
Moron AB	Spain	3	7	7	7	7	3	3	7	5.50
Rota NS	Spain	2	8	9	8	8	2	2	8	5.88
Mildenhall	England	8	6	4	6	5	8	8	6	6.38
Lajes	Potugal	1	9	8	9	9	1	7	9	6.63

	Country	Bahia Blanca	Gao Airfield	Seoul AB	Dili (East Timor)	Baghdad Int'l	Monrovia	Waterkloof	Lahore	Average Rank
Elmendorf AFB	Alaska	1	6	1	1	1	1	4	5	2.50
Kadena AB	Japan	3	1	2	7	2	2	7	1	3.13
Yokota AB	Japan	3	3	3	4	4	5	3	3	3.50
Iwakuni MCAS	Japan	3	2	4	5	3	4	6	2	3.63
Misawa NAF	Japan	3	4	5	3	5	6	2	4	4.00
Hickam AFB	Hawaii	2	7	7	2	7	3	1	7	4.50
Andersen AFB	Guam	3	5	6	6	6	7	5	6	5.50

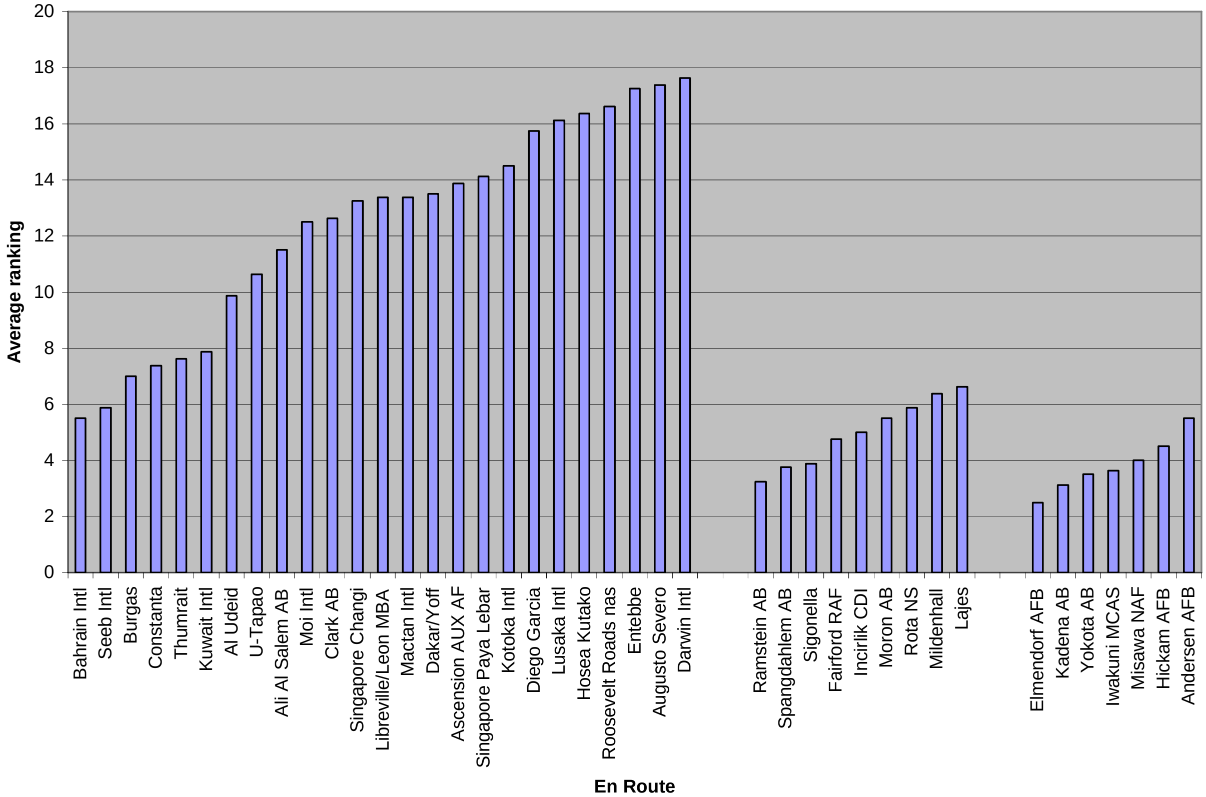


Figure 23. Overall Average Ranking Within Each Set

An important thing to note about the values presented in Table 12 is that the average rankings are based on each particular airfield compared against its own grouping. For example, the average ranking for Ramstein AB is three. This value represents its ranking among the other European en route airfields for which it was compared. Since there are several more potential en route airfields included in the model than European or Pacific en routes, the ability for them to obtain a low (good) ranking of three, four, or five is much more difficult. So the average ranking value of six, which Bahrain International and Seeb International obtained, is quite telling and indicates their high potential as new en route airfields.

Another way to consider the effectiveness of potential en routes from a global perspective is to plot their average *Q* values for destinations to the east of CONUS versus destinations to the West of CONUS. Figure 24 presents such a plot. In this plot en routes that score low *Q* values in both the easterly and westerly directions are preferred, and ideally would be close to the origin. With this in mind, the circle shows the best potential en routes based on their *Q* values. The airfields located within this circle were obtained using equal weighting and the baseline weights. The same potential en route airfields that obtained *Q* values within the circle using baseline weights were still located in the circle using equal weights.

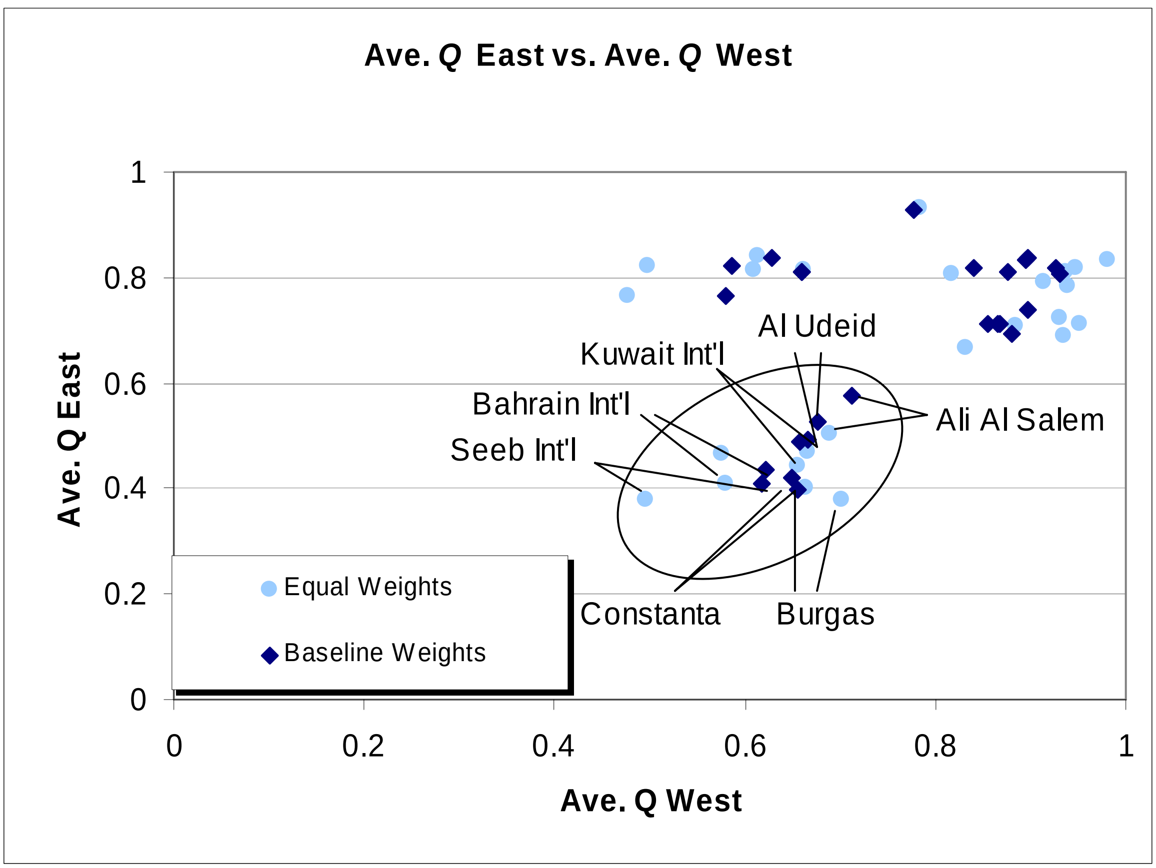


Figure 24: *Q* Values to the East vs. *Q* Values to the West Using Baseline and Equal Weights

Finally, Figure 25 shows an interval plot of *Q* values for each of the 25 potential en routes. That is, this plot shows the mean *Q* value (indicated by the circle) for each en route computed across all 10 origins to all eight potential destinations. The interval plot also contains the upper and lower limits for 90% confidence intervals on each of the *Q* scores. In general, the variability is fairly consistent across the potential en routes. However, the poorly performing en routes tend to have slightly less variance because of frequently scoring a maximum value of one. Ultimately, this plot again confirms the best six potential en routes (i.e., the ones with the lowest mean *Q* values). If the six potential en routes had unusual variance in their *Q* scores, this could have been a concern. However, since their variance is reasonably consistent with the other potential en routes, the interval plot indicates no major issues.

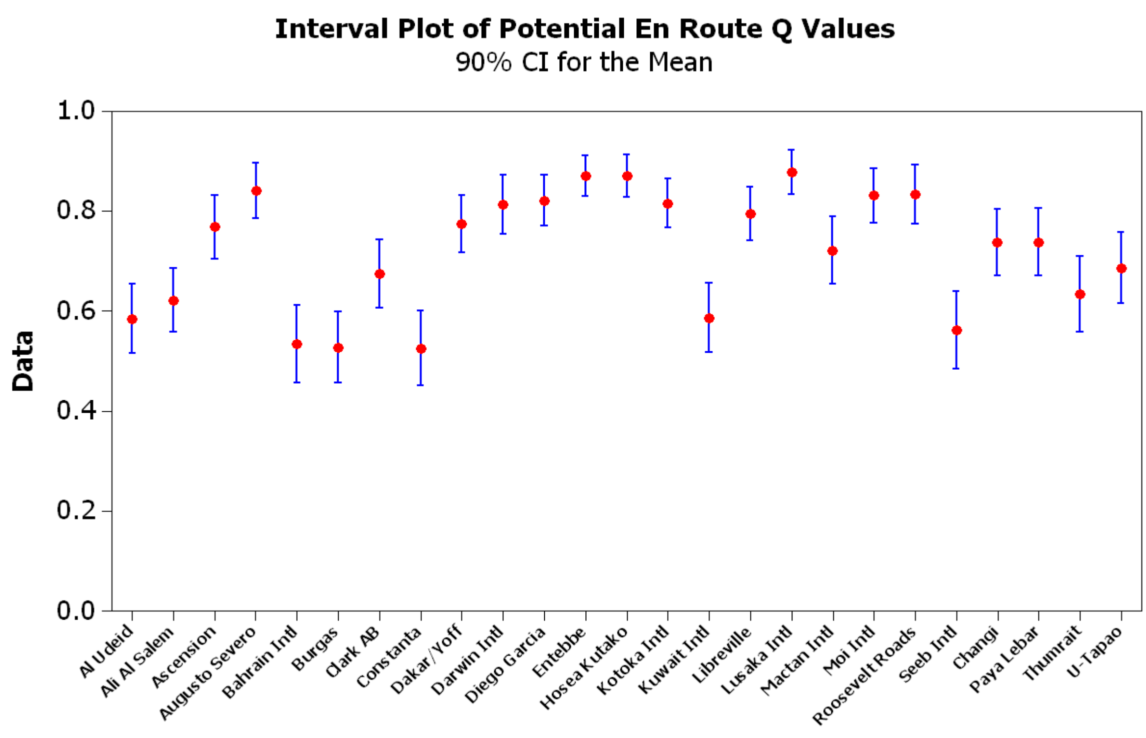


Figure 25. Interval Plot of *Q* Values for Potential En Routes

In summary, this chapter has demonstrated how both the average *Q* values and average rankings obtained by each of the potential en route airfields can yield useful conclusions. There are certain areas of the world where the inclusion of new an en route airfield would be most beneficial. From the *Q* values calculated in the GERST, these areas and their efficiency can be better understood. Conclusions and recommendations will be summarized in the next chapter.

V. Conclusions and Recommendations

Introduction

This section presents a summary of results of the goal programming scoring technique model and corresponding conclusions and recommendations.

Destinations West of CONUS Conclusions

The associated goal programming model results for this region were presented in Chapter IV. The first destination studied in this set was located in Southern South America. For this destination, the top three en route airfields were Roosevelt Roads, Ascension Island, and Augusto Severo respectively. These airfields all received the best *Q* values mainly because of their location with respect to South America. They also stood out because they had better values for the other factors included in the goal program as well, such as high values for MOG or seaport proximity.

For the second destination studied in Southern Asia, the top three potential en route airfields were Seeb International, Bahrain International, and Kuwait International. The fourth and fifth ranked potential en routes were, U-Tapao and Thumrait, which had *Q* values that were just slightly higher than the top three ranked airfields.

The third destination studied in this set was located in Northeast Asia. The top three potential en routes were Clark AB, Mactan International, and U-Tapao respectively. The *Q* values obtained here were slightly worse than those obtained to Southern Asia but still better than those to Southern South America. As more destinations are examined and Q values are computed for these different destinations, alternate en route *Q* value rankings were obtained. By comparing how high or low these rankings are within each region, which destinations are located in hard to reach areas is also indicated. Higher *Q* values for all airfields included in the model suggest that the destination is located either very distant from CONUS and its en route airfields and/or the potential en route airfields are lacking in fuel, MOG, or some of the other goals in the model. The values that each potential en route airfield had for each factor included in the model is presented in Appendix C. By examining the *Q* values, the airfields that have consistently low values for the factors included in the model represent the best, most robust en routes studied.

The final destination located to the west of the United States was located in Southeast Asia. This destination obtained *Q* values for potential en route airfields that was very similar to those obtained for the Northeastern Asia destination. This is to be expected due to the close proximity of these two destinations. Once again the three best en route *Q* values to this destination were Clark AB, Mactan, and U-Tapao. To this destination the ranking of the potential en route airfields are nearly identical. The only thing that stands out as different when studying this destination is that the GERST produced *Q* values are somewhat higher. The ranking of the potential airfields are nearly identical. The *Q* values are somewhat higher, which indicates that travel to Southeast Asia is somewhat more difficult to support than to Northeastern Asia. This result is not that surprising because all the distances are also somewhat greater from CONUS.

Destinations East of CONUS Conclusions

The first destination studied in the area located to the East of CONUS was located in Southwest Asia. Some of the most promising results achieved in this study were found when researching this destination. The two lowest *Q* values obtained for this destination were for Constanta and Burgas. These two airfields are both located in the country of Bulgaria. This country is certainly at a near optimal distance to locate an en route to support travel to the country of Iraq because it is approximately halfway between CONUS and Iraq. This minimizes the deviation from the distance target. In addition to a near optimal en route location, extremely low Q values of approximately 0.5 for both potential en routes suggest that the other factor values included in the model for these airfields are also relatively low. Depending on how these two potential airfields perform to all of the other destinations studied may suggest that they are very good to consider adding as future en route airfields.

The second destination studied in this area was located in Central Asia. For this destination, the best four Q values achieved were located in Seeb International, Bahrain International, Constanta, and Burgas respectively. The values for these four airfields were not only the four best potential en routes for this destination, but the values associated with them were also very low. The values calculated for these potential en route airfields were between 0.2 and 0.3. Compared to the Q value obtained when studying the other destinations, these values are all much lower. Additionally, the potential en routes located in the country of Bulgaria were ranked in the top four again showing promise for these airfields as potential, robust en routes.

The third destination studied was located in Western Africa. Destinations located in the continent of Africa were previously mentioned to be some of the more difficult countries to reach due to their location and scarcity of en routes. For this destination, the airfields with the best three Q values were Dakar, Burgas, and Constanta. Although their Q values are somewhat high, especially when compared to the values achieved by the current en route airfields, they are still respectable considering the average Q values calculated to alternate destinations. Since the values for Constanta and Burgas are once again located in the top three, their overall effectiveness is further suggested. The continued low Q values obtained by the airfields located in Bulgaria suggest that these may be some of the best potential en route airfields to consider.

The final destination considered in this region was located in Southern South Africa. The three lowest *Q* values obtained while studying this destination were Thumrait, Seeb International, and Moi International. While these values can only be considered marginal because they fall between 0.45 and 0.49, they are all lower than any value obtained by the current en route airfields. This lends further credibility to the previous statement that destinations located on the African continent could be in an area that is difficult to have a practical "one stop" en route critical leg distance associated with them, especially if located in the southen part of Africa. Thumrait and Seeb International are also airfields that have scored well in the goal program for this destination. Both of these airfields are located in the country of Oman

Global En Route Conclusions

Having examined which potential en routes are best to eight specific destinations, a global look was considered by examining airfields having good performance in both east and west sets. That is, an average of the *Q* values obtained for each of the destinations provides a more robust way to examine the effectiveness of each particular en route location. A potential en route airfield that obtains a low overall average *Q* value can be viewed as an airfield that can successfully support air travel to missions flown all over the world.

In rank order, the six best average *Q* values obtained by the list of 25 potential en routes consisted of Seeb International, Burgas, Bahrain international, Constanta, Kuwait International, and Thumrait. Both Seeb International and Thumrait are located in the country of Oman. Burgas and Constanta are both located in the country of Bulgaria. Bahrain International is located in Bahrain and Kuwait International is located in the nearby country of Kuwait. These results suggest that airfields located in the countries of Oman, Bulgaria, Bahrain, and Kuwait are good regions to include additional en route airfields. The next assessment that should be conducted is computing potential throughput to the eight global destinations through these en routes based on their infrastructure capabilities.

Future Research

The research done in this study examined 25 potential airfields under consideration by USTRANSCOM and their potential effectiveness in supporting the global war on terrorism as additional en routes for strategic airlift aircraft. Using the GERST developed in this study, these airfields were analyzed based on multiple origins and destinations. Additionally, the current en route airfields were included in the goal program based scoring technique to provide a comparison. The best potential en routes were presented to eight specific destinations and then analyzed globally. As alluded to above, the next appropriate course of action would be to study the best airfields in more detail. In particular, the throughput in terms of Stons/day to each of the eight destinations (or other destinations) should be computed based on these en route infrastructure capabilities or projected infrastructure modernization efforts. Other future research could focus on model refinement such as:

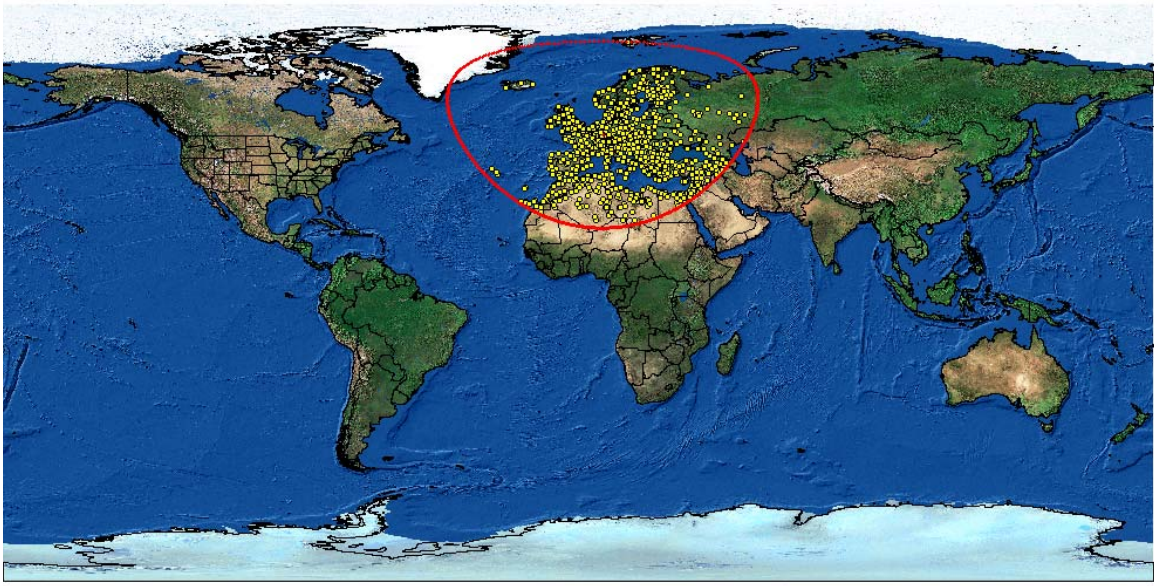
1) Alternate weights associated with each particular factor studied
2) Alternate goals associated with these factors
3) Additional factors included in the model to better study the potential en route airfields
4) Additional or different potential en route airfields included in the goal program
5) Visual Basic code could be used to create a more user friendly spreadsheet
6) Create a model that researches en routes based on multiple waypoint stops rather than the single stop considered here

Of all the changes or additions that could be made to this study, changing the weights or goals presented here is the most likely. While a "100 Ball" approach was taken to determine weights, an alternate approach may be used to determine a different set of factor weights.

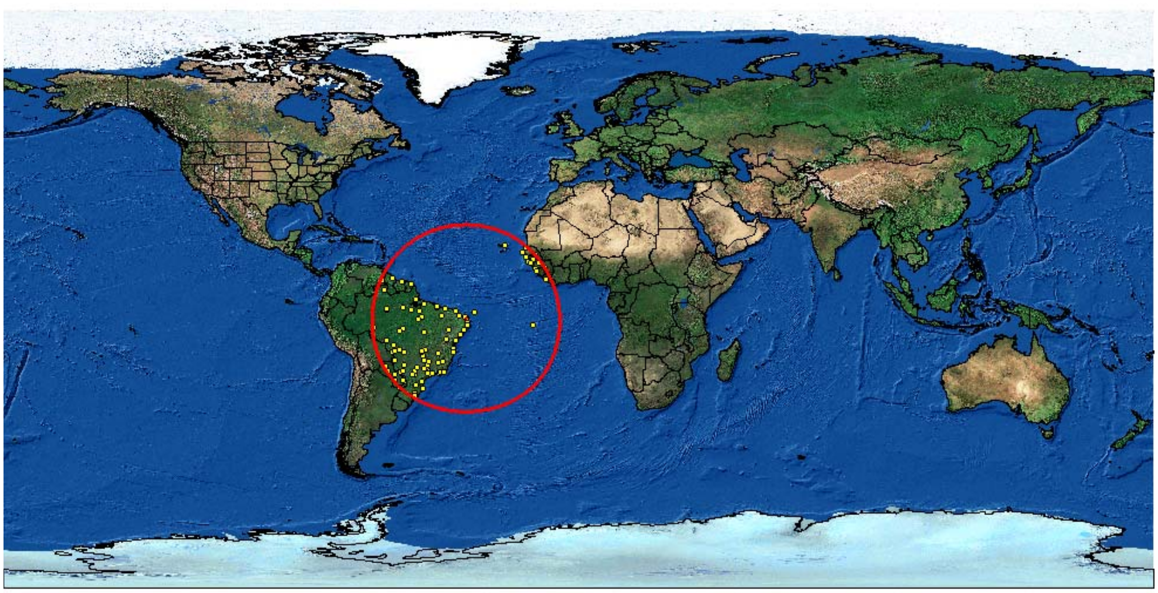
Appendix A. Factorial Experiment Setup

MOG	Fleet Mixture	Distance to en route	Stons/Day
High	50 C-5B	1500 NM	
High	50 C-17 ER	2000 NM	
High	25 C-5B and 25 C-17ER	2500 NM	
High	50 C-5B	3000 NM	
High	50 C-17 ER	3500 NM	
High	25 C-5B and 25 C-17ER	4000 NM	
High	50 C-5B	4500 NM	
High	50 C-17 ER	1500 NM	
High	25 C-5B and 25 C-17ER	2000 NM	
High	50 C-5B	2500 NM	
High	50 C-17 ER	3000 NM	
High	25 C-5B and 25 C-17ER	3500 NM	
High	50 C-5B	4000 NM	
High	50 C-17 ER	4500 NM	
High	25 C-5B and 25 C-17ER	1500 NM	
High	50 C-5B	2000 NM	
High	50 C-17 ER	2500 NM	
High	25 C-5B and 25 C-17ER	3000 NM	
High	50 C-5B	3500 NM	
High	50 C-17 ER	4000 NM	
High	25 C-5B and 25 C-17ER	4500 NM	
High	50 C-5B	1500 NM	
Low	50 C-17 ER	2000 NM	
Low	25 C-5B and 25 C-17ER	2500 NM	
Low	50 C-5B	3000 NM	
Low	50 C-17 ER	3500 NM	
Low	25 C-5B and 25 C-17ER	4000 NM	
Low	50 C-5B	4500 NM	
Low	50 C-17 ER	1500 NM	
Low	25 C-5B and 25 C-17ER	2000 NM	
Low	50 C-5B	2500 NM	
Low	50 C-17 ER	3000 NM	
Low	25 C-5B and 25 C-17ER	3500 NM	
Low	50 C-5B	4000 NM	
Low	50 C-17 ER	4500 NM	
Low	25 C-5B and 25 C-17ER	1500 NM	
Low	50 C-5B	2000 NM	
Low	50 C-17 ER	2500 NM	
Low	25 C-5B and 25 C-17ER	3000 NM	
Low	50 C-5B	3500 NM	
Low	50 C-17 ER	4000 NM	
Low	25 C-5B and 25 C-17ER	4500 NM	

Appendix B. Airfield Reference Tool Example for Ramstein and Augusto Severo



1,013 airfields within 1,750 NM range from European en route – Ramstein



102 airfields within 1,750 NM range from South American en route – Augusto Severo

Appendix C. Potential En Route Airfield Raw Factor Values

Potential En Routes	*m* (MOG)	*f* (Fuel Capacity)	*r* (Dip Relations)	*c* (Seaport Prox)	*a* (Airfields in Range)
Darwin Intl	5	2	3	3	115
Bahrain Intl	12	3	3	3	716
Augusto Severo	12	1	2	3	102
Ascension Island	8	2	3	3	97
Diego Garcia	2	3	3	3	56
Burgas	6	2	2	2	1231
Constanta	6	2	2	3	1216
Libreville	2	2	3	3	217
Kotoka Intl	1	2	2	3	224
Moi Intl	5	3	2	3	253
Ali Al Salem AB	1	3	3	3	785
Kuwait Intl	4	3	3	3	781
Hosea Kutako	6	1	2	2	162
Seeb Intl	16	2	3	3	618
Thumrait	8	2	3	3	604
Clark AB	8	3	2	3	336
Mactan Intl	6	2	2	3	306
NAS Roosevelt Roads	8	1	3	3	515
Al Udeid	3	2	3	3	705
Dakar	1	2	3	3	182
Changi	15	3	3	3	237
Paya Lebar	10	3	3	3	234
U-Tapao	10	3	3	3	296
Entebbe	2	1	2	1	312
Lusaka Intl	6	1	2	1	198

Bibliogaphy

Brigantic, R. and D. Merrill. “The Algebra of Airlift” *Defense Transportation Algorithms, Models, and Applications for the 21st Century*, Amsterdam: Elesevier, 649-656, 2004.

Clemen, R. and T. Reilly. *Making Hard Decisions with DecisionTools 2004*, Pacific Grove, CA: Duxbury, 2001.

Department of the Air Force. *Air Mobility Planning Factors*, AFPAM 10-1403, Washington: Government Printing office, March 1998.

Goicochea, A., L. Duckstein, and D. Hansen. *Multiobjective Decision Analysis with Engineering and Business applications*. New York: John Wiley and Sons, 1982.

Kirkwood, C. *Strategic Decision Making: Multiobjective Decision Analysis with Spreadsheets*, Belmont, CA: Wadsworth Publishing Company, 1997.

Mahan. J., Hankins, L., and Koch, R. “Airfield Infrastructure and Throughput Analysis Study for Strategic Airlift,” Scott AFB, IL: USTRANSCOM/AMC, Sep 2002.

McVicker, P. “En Route Strategic Plan” Report to USTRANSCOM/J5, Scott AFB, IL: AMC/XP, February 2002.

Pelletier, D. *Probability Distribution Analysis of Air Mobility Planning Factors*, USAF IDE Graduate Research Paper, AFIT/MLM/ENS/04-08. School of Engineering and Management, Air Force Institute of Technology (AU), Wright Patterson AFB OH, September 2004.

Reckamp, K. and Others, *Interim Brigade Combat Team Air Mobility Deployment Analysis*, Military Traffic Management Command, Transportation Engineering Agency (MTMC-TEA), USTRANSCOM/J5, and Air Mobility Command (AMC), 26 April 2002.

Swartz, K. “Great Circle Mapper Utility Tool.” http://gc.kls2.com. 15 February 2004.

U.S. Department of State website, http://www.state.gov/r/pa/ei/bgn. 19 October 2004.

U.S. General Accounting Office, “MILITARY READINESS: Management Focus Needed on Airfields for Overseas Deployments”, GAO-01-566, Washington: Government Printing office June 2001.

Vita

Captain Michael C. Sere graduated from Amphitheater High School in Tucson, Arizona in June, 1995. He entered undergraduate studies at the United States Air Force Academy (USAFA) where he graduated with a Bachelor of Science Degree in Operations Research in May 2000. He was commissioned through USAFA with a Reserve Commission.

His first assignment was at Lackland AFB as an operations research analyst for the 453 Electronic Warfare Squadron, 318 Informations Operations Group, Air Force Information Warfare Center. In August 2004, he entered the Graduate School of Engineering and Management, Air Force Institute of Technology. Upon graduation, he will be assigned to the Air Force Operational Test and Evaluation Center, Kirtland AFB, New Mexico.

REPORT DOCUMENTATION PAGE			*Form Approved* *OMB No. 074-0188*
The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of the collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to an penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**			
1. REPORT DATE *(DD-MM-YYYY)* 21-03-2004	**2. REPORT TYPE** **Master's Thesis**		**3. DATES COVERED** *(From – To)* June 2004 – Mar 2005
4. TITLE AND SUBTITLE STRATEGIC AIRLIFT EN ROUTE ANALYSIS AND CONSIDERATIONS TO SUPPORT THE GLOBAL WAR ON TERRORISM			**5a. CONTRACT NUMBER** **5b. GRANT NUMBER** **5c. PROGRAM ELEMENT NUMBER**
6. AUTHOR(S) Sere, Michael, C., Captain, USAF			**5d. PROJECT NUMBER** **5e. TASK NUMBER** **5f. WORK UNIT NUMBER**
7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S) Air Force Institute of Technology Graduate School of Engineering and Management (AFIT/EN) 2950 Hobson Street, Building 642 WPAFB OH 45433-7765			**8. PERFORMING ORGANIZATION REPORT NUMBER** AFIT/GOR/ENS/05-17
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) AFSOR/NM, Attn: Dr. Neal Glassman, 4015 Wilson Boulevard Mail Room 713Arlington, Virginia 22203-1954 Phone: (703) 696 -9548 E-mail: neal.glassman@afosr.af.mil			**10. SPONSOR/MONITOR'S ACRONYM(S)** **11. SPONSOR/MONITOR'S REPORT NUMBER(S)**
12. DISTRIBUTION/AVAILABILITY STATEMENT APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.			
13. SUPPLEMENTARY NOTES			

14. ABSTRACT

The Global War on Terrorism has mandated the need for additional global en route airfields. En route airfields consist of bases that are strategically located at intermediate locations between the Continental United States and the intended theater of operations. These airfields serve as refueling, crew staging, or maintenance stops for strategic airlift aircraft flying transoceanic routes. The focus of this study is to examine concepts to meet this need and to address important aspects that should be considered in devising new en route strategies. Based on various important factors associated with potential en route airfields, a goal programming methodology was used to develop an Excel based tool to aid the decision process for selecting the best future en route airfields and potential infrastructure improvements at those airfields. The factors included in this tool consist of 1)the distance from various origins to the en route of interest and the distance from the en route to various destinations, 2) the amount of parking capacity available at potential en route airfields, 3) the fuel capability present at these airfields to support strategic aircraft flow, 4) diplomatic relations with the en route host countries, 5) airfield distance from coastal seaports, and 6) the number of strategic aircraft capable airfields within a predetermined range of the potential en route. Using the developed goal program tool, 25 potential en route airfields used to transit to eight global destinations from ten different origins were studied. With the above factors assessed and examined, conclusions relating to which potential en route airfields would be the most beneficial in fighting the Global War on Terrorism are delineated.

15. SUBJECT TERMS
Goal Program, En Route, Global War on Terrorism, Future En Route Airfields, Strategic airlift

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Robert Brigantic, Lt Col, USAF (ENS)
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(Include area code)* (937) 255-3636, ext 4624; e-mail: robert.brigantic@afit.edu
U	U	U	UU	91	